DISTRIBUTION AND ABUNDANCE OF *LATES NILOTICUS* (L.) AND *OREOCHROMIS NILOTICUS* (L.) IN LAKE VICTORIA, UGANDA.

BY

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DECLARATION

I, **OKARONON JOHN OBBO**, declare that this thesis is my original work and has not been submitted for a degree in any other University

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DEDICATION

I dedicate this thesis to my late parents, Alonsio Okaronon (died 13 May 1988) and Bernadette Awor Okaronon (died 25 February 1971), and my late sons, Francis Olukudo (died 4 April 1989) and Peter Oboth (died 4 January 1995); they could not live long enough to share with me the joy and benefits of this achievement. MAY THE ALMIGHTY GOD REST THEIR SOULS IN ETERNAL PEACE.

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ABSTRACT

Bottom trawls, gill nets and other sampling devices were used to study the distribution and abundance of Nile perch (*Lates niloticus* (L.)) and Nile tilapia (*Oreochromis niloticus* (L.)) in the Uganda portion of Lake Victoria from 1999 to 2001.

A total of 17 fish taxa (belonging to 14 genera) were encountered in the Uganda portion of Lake Victoria in this study. This reflects a decline in fish species diversity over the last 30 years when compared with results from similar studies in 1969/71. *Tilapia rendalli* was encountered for the first time since it was introduced in 1950s. The fish catch was dominated by *Lates niloticus* (86.5% by weight), followed by *Oreochromis niloticus* (9.8%). *L. niloticus* was found in all areas surveyed while *O. niloticus* was restricted to waters <20 m deep.

The highest catches (13.7±1.1 t km^{-2}) of *L. niloticus* in bottom trawls were obtained in Zone I – between Tanzania/Uganda border and Bukakata - and Zone III – between Kiyindi and Uganda/Kenya border - had the lowest concentrations of fish (8.3±0.6 t km^{-2}). This trend was also reported during the period 1993/98.

Length frequency data for *L. niloticus* suggest that all size groups were found in all areas surveyed during bottom trawling. Juveniles of *L. niloticus* of less

than 6 cm TL were found in all areas surveyed. This may suggest that breeding of *L. niloticus* takes place throughout the lake.

O. niloticus during the bottom trawl surveys in 1999/2000 were restricted to water <20 m deep. The bulk of (93% by weight and 40% by numbers) *O. niloticus* were mature (>22 cm TL). This was partly because trawling covered only waters 4-60 m deep leaving the waters <4 m deep, a potential area for the small, young fish of the species.

In the monofilament gill net surveys, *L. niloticus* dominated the catches in the open deep water while *O. niloticus* dominated in the shallow inshore areas. In the open deep water areas the nets set at the bottom did not catch fish; this was attributed to low oxygen levels.

More male than female *L. niloticus* were caught during both the bottom trawl and gill net during the survey period.

The fish stock densities (CPUA) in the bottom trawls have continued to decline from 36.2 t km^{-2} for all fish taxa during 1969/1971 to 8.8 t km^{-2} for *L. niloticus* in the present study in the 4-30 m deep waters. Fish stock densities of *O. niloticus* were higher in 4-10 m deep water than in waters 10-20 m deep.

The biomass of 121 000 t of *L. niloticus* and 12 000 t of *O. niloticus* were estimated in the 4-40 m water depth zone. These estimates increased from 117 053 t in 1999 to 121 930 t in 2000 for *L. niloticus* and from 7316 t in 1999 to 17 070 t for *O. niloticus*. Such increases may partly have been due to the El-Nino rains of 1998/1999, the reduction in fishing pressure resulting from the ban of export of fish and fish products from the Uganda portion of Lake Victoria to the European Union during 1999.

Juvenile fish measuring <50 cm TL (size at first maturity for male *L. niloticus*) constituted 72.5% of the catch by weight while 27.5% were mature fish. Accordingly, about 32 800 tonnes of the 119 491 tonnes estimated for *L. niloticus* in the 4-40 m water depth zones during the survey period 1999-2000 were mature fish. The bulk of the immature *L. niloticus* were caught in waters <20 m deep (63.36 % by numbers) and in Zone III where they (immature fish) contributed 99.02% (by numbers) during 1999-2000. The abundance of the juvenile fish of various sizes promises good future recruitment to the population while the relatively small numbers of large mature fish raises concern on the future of the fishery.

In this study the asymptotic lengths (L_∞) for *L. niloticus* and *O. niloticus* were estimated as 256 cm and 75 cm TL, respectively, while the respective growth rates for the two species were 0.29 yr^{-1} and 0.40 yr^{-1}. The size at first maturity for male and female *L. niloticus* were 50 cm and 64 cm TL, respectively, while the size at first maturity for *O. niloticus* were 21.5 cm and 22.5 cm TL for male and female, respectively. The high mortality rates for both *L. niloticus* (Z=1.91) and *O. niloticus* (Z=1.65) increased from 1999 to 2000 and varied between zones.

During this study, recruitment in the fisheries of *L. niloticus* and *O. niloticus* occurred throughout the year but with two peak periods. Peak recruitment for both *L. niloticus* and *O. niloticus* occurred during the rainy season (March-May and August-November).

The diet of *L. niloticus* varied with its size. *Caridina nilotica* formed the most important food item in juvenile fish up to 40 cm TL. Fish and fish remains were observed from fish specimens as young as 6.2 cm TL. The occurrence of fish in the diet of *L. niloticus* increased with increasing size of the fish specimens, becoming dominant (67.4% occurrence) in fish of 40 cm TL and contributing about 100% of the diet in fish of 90 cm TL.

During this study the water temperature varied in the different habitats and seasons but generally ranged from 28.1°C at the surface to 24°C at the bottom. Dissolved oxygen, a requirement for all living things, varied with water depth, season and habitats. The varied distribution of the fish during this study was considered to have been influenced by the observed distribution of oxygen. The high catches of fish in the 20-30 m depth area in Zone I is likely to be due to the presence of sufficient oxygen in the area. The low abundance of fish in waters >25 m deep are partly due to insufficient or no oxygen.

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CHAPTER 1

1.0. INTRODUCTION

During the last 30 years changes (physical, chemical and biological) have occurred in Lake Victoria and, consequently, the fish stocks have been modified. The extent of the modification of the fish stocks, especially the distribution and abundance of *Lates niloticus* (Linnaeus, 1758) (Plate 1) and *Oreochromis niloticus* (Linnaeus, 1767) (Plate 2), is not fully known. Although environmental and other ecological changes have been recognised to have influenced the changes in the fish stocks of Lake Victoria (Ochumba, 1988; Hecky & Bugenyi, 1992; Hecky *et al*., 1994), these have not been directly linked to the changes in the fish stocks.

Lake Victoria had a multi-species fishery dominated until the 1970s by the tilapiines and the haplochromine cichlids, but with important subsidiary fisheries of more than 20 genera of non-cichlid fishes such as *Bagrus*, *Barbus*, *Clarias*, *Mormyrus*, *Protopterus*, *Synodontis*, etc. (Kudhongania & Cordone, 1974). Stocks of most of these species declined and others disappeared following the introduction of four tilapiine species (*Oreochromis niloticus, O. leucostictus*, *Tilapia rendalli*, and *T. zillii*) during the 1950s and the Nile perch (*Lates niloticus*) during the 1960s. Since then the fishery has been dominated by *L. niloticus, Oreochromis niloticus* and one endemic cyprinid *Rastrineobola argentea* (Okaronon, 1994). The only fish stock assessment exercise in Lake

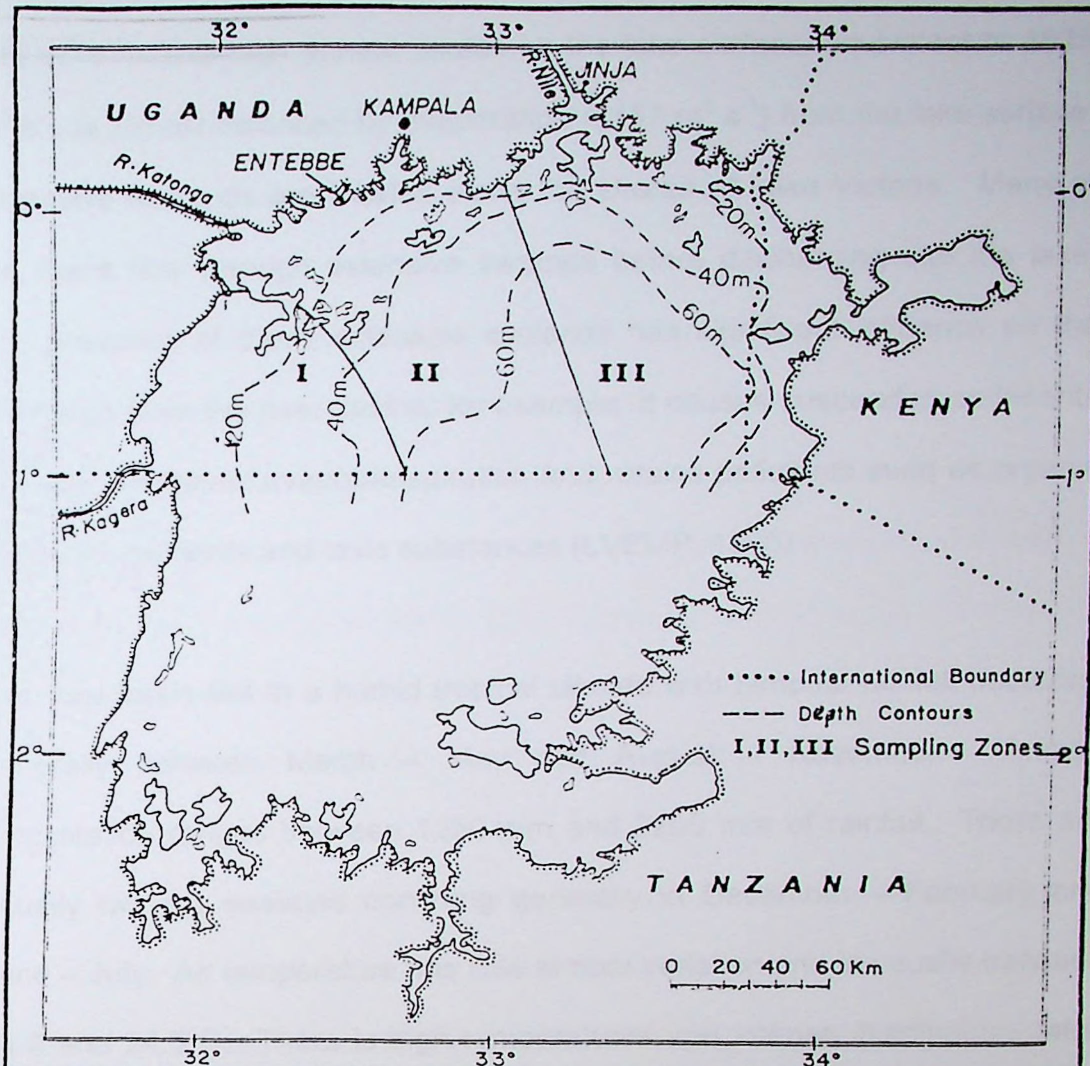
Plate 1. *Lates niloticus* (Nile perch) [Photo against a 1-metre measuring board]

Plate 2. *Oreochromis niloticus* (Nile tilapia) [Photo against a BiC biro pen]

Victoria was undertaken during 1969/71 (Kudhongania & Cordone, 1974) before the Nile perch upsurge.

Lake Victoria is the second largest lake in the World with an area of 68 800 km^2. It lies across the Equator between 0° 30'N – 3° 00'S and 31° 39' –34° 53'E. The lake surface area of 68 800 km^2 is distributed between the riparian states of Kenya (6%), Uganda (43%) and Tanzania (51%). It lies at an altitude of 1135 m above sea level and is situated between the great plateau stretching between the western and eastern rift valleys. It is a shallow saucer shaped basin with maximum depth of 84 m, mean depth of 40 m, maximum length of 400 km and maximum width of 240 km. Its land catchment area of 193 000 km^2 is distributed as follows: Tanzania 44%, Kenya 22%, and Uganda 16%, Rwanda 11% and Burundi 7% (LVEMP, 1996). The lake shoreline is approximately 3450 km, of which 50% (1750 km) is in Uganda, 33% (1150 km) is in Tanzania and 17% (550 km) is in Kenya. The shoreline has numerous sheltered bays and gulfs that makes it very irregular and impart heterogeneity and ecological differentiation on the lake limnochemistry and biota (Fig. 1).

The main input into the lake is direct rainfall that contributes about 85%, while inflow from the tributaries is 15%. The River Kagera is the major contributor accounting for about 44% of the inflow (LVEMP, 1996). Meanwhile the major output is through evaporation with the only outflow being via the Owen Falls Dam in Jinja in Uganda by the Victoria Nile River. The average outflow during 1948 –1970 was 914 $m^3 s^{-1}$, about 75% of the outflow of the Nile at Uganda –



Sampling zone on the Uganda sector:

I. Tanzania/Uganda border to Bugoma Channel (Bukakata).
II. Bugoma Channel to Rosebury Channel (Kiyindi).
III. Rosebury Channel to Uganda/Kenya border.

Figure 1. Map of Lake Victoria showing depth contours and sampling zones on the Uganda sector during bottom trawl surveys between January 1999 and December 2000.

Sudan border. Estimated total input from the land catchment of the basin is 596 $m^3 s^{-1}$. The high annual rainfall on the lake surface, equivalent to 3625 $m^3 s^{-1}$, is almost balanced by evaporation (3157 $m^3 s^{-1}$) from the lake surface. Extensive wetlands are located along the shores of Lake Victoria. Many of the rivers flow through extensive swamps before discharging into the lake. The presence of these extensive wetlands has significant influence on the discharge from the river basins; for example, it causes suspended sediments to settle, increases evapotranspiration and retains pollutants such as organic materials, nutrients and toxic substances (LVEMP, 1996).

The lake basin lies in a humid tropical climate with bimodal rainfall occurring generally between March – May and August – November. Annual precipitation ranges between 1250 mm and 2200 mm of rainfall. There are usually two dry seasons occurring generally in December – February and June – July. Air temperature has little annual variation and is usually between 21.0 and 24.5°C. There is high temperatures and intense illumination, lake-wide evaporation estimated at 1595 mm per year. There is, therefore, a prolonged growing season in the lake basin typical of tropical regions.

The lake and its inflowing rivers contribute significantly towards ecological, bio-physical, cultural and socio-economic development along its shoreline, catchment area, within the islands as well as the livelihood of the communities far and beyond its catchment area. It is estimated that over 20 million people in the basin derive their livelihood directly and indirectly from the lake and its catchment (LVEMP, 1996). The lake is, therefore, highly relied upon by the riparian states for food, hydropower generation, transport and communication, tourism, water supply for domestic, agricultural and industrial use, waste water disposal, recreation, sport and biodiversity conservation. The lake also modulates weather and climate.

The dominant socio-economic activities in the lake and its catchment include agriculture, fisheries, marine transportation, recreation, and water supplies for domestic and industrial use in the urban centres on its shoreline. Agriculture and fishing remain the mainstay and indeed the dominant socio-economic activity of most of the population within the catchment area, though mining is also an important economic activity around Mwanza and Mara regions in Tanzania. Urban development is also on the increase.

In recent years, the population around the lake and within its basin has grown very rapidly at an average rate of 3 percent. The high rate of rural-urban migration in the region has resulted in an average annual growth rate of over 3.5% in the major urban areas. These include Kisumu, Eldoret, Homa Bay, Bungoma, Kakamega, Kisii and Kericho (Kenya), Kampala, Jinja, Masaka, Entebbe, Mbarara (Uganda) and Mwanza, Bukoba and Musoma (Tanzania).
The rural areas in the basin constitute some of the high agricultural potential areas in the region. Their productivity has, however, been undermined by the high annual population growth rate of over 3%. This has precipitated serious environmental degradation arising from substantial pressure on the limited land and water resources.

Stocks of most of the native species have declined and others have completely disappeared following the establishment of the introduced Nile perch, *Lates niloticus* (Ogutu-Ohwayo, 1990a, b; Witte *et al.*, 1992; Ogari & Dadzie, 1988). Predation by the Nile perch is thought to be the main cause of the depletion of the fish stocks. However, overfishing (Jackson, 1971), competition between introduced tilapiines (*Oreochromis niloticus, O. leucostictus*, *Tilapia rendalli,* and *T. zillii*) and native cichlids (Ogutu-Ohwayo, 1990a, b) and environmental degradation (Hecky & Bugenyi, 1992; Hecky, 1993; Mugidde, 1993) have contributed to the changes and are likely to play a major role in the stability of the current fisheries of Lake Victoria. The fishery is now dominated by the introduced *L. niloticus* and *Oreochromis niloticus* and one endemic cyprinid *Rastrineobola argentea* Pellegrin 1904 (Okaronon, 1994).

Bottom trawling in the Ugandan waters of Lake Victoria during 1981-1985 (Okaronon *et al.*, 1985; Okaronon & Kamanyi, 1986) showed that the Haplochromines 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. 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. The mean catch rates for all fish species combined in the 4-30 m water depth zone declined from 797 kg hr-1 during 1969/71 to 595 kg hr^{-1} in 1981, to 355 kg hr^{-1} in 1983, to 155 kg hr^{-1} in 1985 and 119 kg hr^{-1} in 1998 (Appendix 1) (Okaronon *et al.*, 1999).

The total catch from the Ugandan waters of Lake Victoria fluctuated around 35 000 tons between 1961 and 1969, declined during the 1970s and early 1980s before beginning to pick up again in 1983 (Appendix 1). Lake Victoria was leading fish production up to 1969 during which period it was contributing between 30% and 40% of national fish production. During 1990, fish production from Ugandan waters of Lake Victoria was estimated at 119 900 tons (49% of national fish production) down from 132 400 tons (62% of national fish production) during 1989 and 135 000 tons (48.8% of national production) in 1993. Fish production in Lake Victoria (Uganda) has been fluctuating between 103 040 tons (47.1%) and 106 000 tons (48.5%) since then. Meanwhile, the initial catch rates in 127 mm mesh size of gill nets of 45 m length ranged between 50 fish (37.5 kg) and 100 fish (75 kg) of tilapia (*Oreochromis esculentus*) net^{-1} night^{-1} but by 1968 the catch rates had declined to 0.35 fish (0.3 kg) net^{-1} night^{-1} (Jackson, 1971). In 1989, the catch for all fish in the 127 mm mesh gill nets fished in Lake Victoria was 2.5 kg net^{-1} night^{-1} (Okaronon & Kamanyi, 1989); the catch had further reduced to less 1 kg net^{-1} night^{-1} for all fish species by 1997 (Okaronon *et al.*, 1999).

The increase in total yield in Lake Victoria following the establishment of introduced species, especially the Nile perch, was accompanied by intensified fishing effort. The number of fishing boats in the Ugandan region of Lake Victoria alone increased from 3264 in 1971 to 8674 in 1990 (Wetherall, 1972; Tumwebaze & Coenen, 1991); the Frame Survey of March 2000 estimated the number of fishing boats at 16 093 (Asila 2001, Uganda Fisheries

Resources Department 2001). Use of destructive fishing gears such as seine and cast nets has also increased. The fisheries of Lake Victoria are subjected to very high fishing pressure. The increase in fishing pressure has been fuelled by the growing human population as well as by an expansion of an export market for chilled and frozen Nile perch fillets. Fish processing factories, which were non-existent prior to the establishment of the Nile perch, have been constructed, 11 of which are licensed to operate in the Ugandan sector of the lake (Odongkara & Okaronon, 1999). The increase in fishing effort and investment were made without a clear knowledge of the magnitude and sustainability of the stocks. There are indications that the fishery yield in the Uganda sector declined from 135 000 tons in 1993 to 107 000 tons in 1997 (Odongkara & Okaronon, 1999).

The rapid increases in Nile perch stocks and depletion of native species occurred concurrently with changes in the physical and chemical conditions and biological characteristics of Lake Victoria (Ochumba & Kibaara, 1989; Hecky & Bugenyi, 1992; Hecky, 1993; Mugidde, 1993). For example, an increase in nutrient inputs into the lake especially from the atmosphere and from changes in land use in the catchment area has been reported (Bootsma & Hecky, 1993) and are thought to have stimulated algal production and changes in the taxa of dominant algae (Mugidde, 1993). Algal biomass is now four to five times higher than the mean values of the 1960s and phytoplankton production has doubled (Mugidde, 1992, 1993). Water transparency has decreased to a quarter of what it was during the 1960s. The algae are dominated by Cyanobacteria that are not readily consumed by fishes (Mugidde, 2001). Decay of the excess organic matter depletes the water column of Oxygen. This has led to development of anoxic water in deepest parts of the lake (>40 m). Oxygen concentration in the hypolimnion during the period of stratification has decreased and anoxia now occurs for longer periods and extends to shallower depths (Hecky, 1993; Hecky *et al.*, 1994). This has, and will as it expands, reduce habitable space for many fish species.

Lake Victoria was invaded by the water hyacinth, *Eichhornia crassipes,* in 1990 (Twongo, 1991). This plant thrives in shallow, sheltered bays that are suitable breeding and nursery grounds for many fish species. It can, therefore, affect breeding success and feeding by juvenile fishes. The zone below extensive areas of hyacinth mats is low in Oxygen, which reduces habitable space for most fish and other organisms upon which fish may feed.

Further, the prevailing threat of eutrophication, algal blooms and the spread of water hyacinth threatens to reduce substantially the average annual fish catches of between 400 000 – 500 000 metric tonnes. This represents a serious loss of income to the artisanal fishermen along the lakeshore, loss of the main protein source for the local as well as national communities in the riparian states. In addition to undermining food security, it also deprives the national treasuries of the much needed foreign exchange earned through fisheries and tourism.

It is evident from the above that there is need to undertake research to assess the status of the fish stocks of Lake Victoria after the establishment of the Nile perch. It is particularly necessary to determine the distribution and abundance of the two fish species currently dominating the fishery (*L. niloticus* and *O. niloticus*) in the entire lake. The information obtained from the study will contribute toward the sustainable management of the fisheries of Lake Victoria.

In this study, the distribution and abundance of *L. niloticus* and *O. niloticus* were investigated during the period January 1999 to December 2000, through bottom trawl surveys, and through multi-mesh gill net surveys during the period November 1999 to September 2001.

1.1. **Justification**

Lake Victoria offers the riparian states considerable potential for economic employment and nutritional values. The yield is declining and the demand for fish is increasing, especially for the export market. All this is happening when there is considerable uncertainty regarding qualitative and quantitative nature of the fish stocks and their dynamics.

1.2. **Objectives**

The overall objective of the study was to understand the fish stocks dynamics with particular reference to the distribution and abundance of *Lates niloticus* and *Oreochromis niloticus* in relation to environmental and other factors associated with Lake Victoria (Uganda).

The specific objectives of the study included:

1. An assessment of the spatial and temporal distribution of *L. niloticus* and *O. niloticus.*
2. An assessment of the population dynamics of *L. niloticus* and *O. niloticus.*
3. A determination of the factors responsible for the distribution and abundance of *L. niloticus* and *O. niloticus.*

Under these objectives, the test hypotheses were:

(a). The fish are restricted to shallow water areas of the lake.

(b). The fish stock abundance in Lake Victoria is declining.

1.3. **Expected outputs**

The expected outputs of the study included:

1. The distribution of *L. niloticus* and *O. niloticus* in both temporal and spatial scales.
2. The size structure and population characteristics of *L. niloticus* and *O. niloticus.*
3. The relative abundance of *L. niloticus* and *O. niloticus* in both temporal and spatial scales.
4. The factors which influence the distribution and abundance of *L. niloticus* and *O. niloticus*

CHAPTER 2

2.0. LITERATURE REVIEW

2.1. Fish stock distribution and abundance

During the 20th century dramatic changes occurred in Lake Victoria due to human intervention (Graham, 1929; Ochumba & Kibaara, 1989; Ogutu-Ohwayo, 1990b). During the first half of the century, fishing pressure increased constantly. Railway lines reached the lake and opened new urban market areas for the lake (Graham, 1929). Between the 1930s and 1940s the catches of the tilapiine fishery declined strongly (Fryer & Iles, 1972). In the 1950s fishing techniques became more efficient due to the introduction of nylon nets and outboard engines, but the catches dropped further. Fishermen started the use of illegal mesh sizes and the minimum mesh of 5" (127 mm) was officially repealed in the second half of the 1950s, resulting in a short revival and a subsequent further decline of fish catches (Fryer & Iles, 1972). Because of the decreasing catches of native species, exotic tilapiine cichlids (and other fishes) were introduced into the lake in the 1950s, to fill supposedly empty niches (Welcomme, 1967); in the same period a huge predator, the Nile perch, was introduced. This species, which was a popular food fish already in ancient Egypt, was expected to prey upon the small and bony haplochromines.

The first fish stock assessment survey of Lake Victoria was undertaken during 1969/71 (Kudhongania & Cordone, 1974) before the Nile perch upsurge. The survey results included the following observations:

1. Twenty four fish species belonging to 21 genera were encountered and haplochromine cichlids were the most abundant.
2. There were remarkable changes in species composition by depth with the maximum species diversity in the shallow waters.
3. 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 *Synodontis victoriae* 0.4%. *Lates niloticus* catches were insignificant (<0.1%).
4. A mean catch rate of 797 kg hr^{-1} was estimated for waters between 4 m and 30 m deep.
5. The mean total length of some fishes (*Haplochromis* spp, *S. victoriae*, *Xenoclarias eupogon*) increased with depth.

Since 1977, considerable attempts have been made to conduct surveys aimed at assessing the status of the fish stocks in Lake Victoria. Surveys were conducted in the Nyanza Gulf (Okemwa, 1981, 1984; Asila, 1984), the Mwanza waters (Katunzi, 1985; Mkumbo & Ligtvoet, 1992) and in the Jinja waters of the lake (Okaronon *et al.*, 1985; Acere, 1988; Wandera, 1990). These surveys indicated that although Lake Victoria still had a number of fisheries based on some 17 species groups, most species were on the decline and that the inshore waters indicated a growing dominance by three fish taxa, the introduced *L. niloticus* and *O. niloticus* and the native *R. argentea*.

A study of the species composition, average size and ecological distribution of the fish stocks was carried out –using experimental bottom trawl nets – in Napoleon Gulf, Buvuma Channel and Lingira Bay of Lake Victoria (Uganda) by Okaronon *et al.* (1985) between 1981 and 1983. This study revealed that the *Haplochromis* species declined from 543.3 kg hr^{-1} in 1981 to 270.8 kg hr^{-1} in 1983 while *L. niloticus* increased from 0.5 kg hr^{-1} to 57.5 kg hr^{-1} during the same period. By 1984 the Nile perch was contributing over 50% of the total commercial tonnage while in the experimental trawling catch it contributed 68% of total catch (Acere, 1985). Haplochromines contribution in the bottom trawl survey in the Northern portion of the Uganda waters of Lake Victoria further declined to 17.8 kg hr^{-1} (0.9% of total catch) in 1985 while the contribution of *L. niloticus* in 1985 was 234.7 kg hr^{-1} (90.4%) (Acere 1988).

From the limited – spatially and temporally - bottom trawl stock assessment surveys of the Uganda portion of Lake Victoria since 1981, Okaronon (1994) observed a species diversity reduction. Only 14 fish species (11 genera) (excluding the haplochromines) were recorded from the 25.4 mm mesh codend trawl net during the 1993/94 survey. This reflected a species diversity reduction down to about half of the 1969/71 survey results by Kudhongania and Cordone (1974). The fish species diversity decreased with increasing water depth; only two fish taxa (*L. niloticus* and haplochromines) were recorded in waters deeper than 30 m during the 1993/94 survey. The author further observed a decline in catch rates in the 4-30 m depth zone for all fish species combined from 797 kg hr^{-1} in 1969/71 to 595, 365, 355, 155 and 154 kg hr^{-1} in 1981, 1982, 1983, 1985 and 1993/94, respectively. The haplochromine group, which dominated up to 1983, declined drastically and in the 1993/94 surveys it contributed only 0.2% of the catch by weight. On the contrary, *L. niloticus* which was unimportant in 1969/71 (at 1 kg hr^{-1} (0.1% of the catch)) increased and contributed 5, 42, 58, 148 and 148 kg hr^{-1} - 0.5, 11.5, 16.3, 95.5 and 96.1% of the total catch – in the 4-30 m depth zone during the 1981, 1982, 1983, 1985 and 1993/94 surveys, respectively.

In the Mwanza waters, bottom trawl surveys conducted from 1986 to 1989 on the general ecology and population dynamics of the Nile perch, *L. niloticus*, Ligtvoet and Mkumbo (1990) observed that *L. niloticus* occurred in all habitats surveyed. The highest catch rates were obtained from waters 16-35 m deep. In another study on the Nile perch fishery in the Mwanza waters of Lake Victoria, Goudswaard and Ligtvoet (1988) observed that the introduced *Lates niloticus* had established itself in the major part of the lake and was supporting the most important fishery. With the exponential increase in Nile perch, the haplochromine stock, formerly encompassing more than 80% of the total fish stock, had correspondingly decreased or even been lost. The authors also observed that although Nile perch was generally believed to be a shallow water species, the highest catch rates of Nile perch in southern Lake Victoria were obtained from deeper waters (16-35 m).

Bottom trawl studies in the Nyanza Gulf of Lake Victoria during the period August 1981-July 1982 showed that *L. niloticus* had colonized the whole of Nyanza Gulf (Ogari, 1985). The post larvae and juvenile *L. niloticus* inhabited mainly the shallow inshore areas and there was an increase in the size of *L. niloticus* with increase in water depth. Highest catches were realized within the mid-deep offshore areas (12-16 m).

Balirwa (1998) investigated 'Lake Victoria wetlands and the ecology of the Nile tilapia, *Oreochromis niloticus* Linne'; the investigation area was the Napoleon Gulf near Jinja and fish specimens obtained using multi-mesh gill nets. At least 30 species of fish were found in the shallower (2.5 m) vegetated habitats in contrast to 10 species in the deeper (4-8 m) open water habitats. Species diversity was dominated by haplochromine species but three introduced species (*Lates niloticus, O. niloticus* and *Tilapia zillii*) contributed at least 90% of the estimated biomass densities, of which the Nile tilapia was the most important component making up 45-65% of the biomass of all fish. The shallow vegetated habitats were found to be ecologically important for the Nile tilapia for sheltering and feeding.

Chandler and Ogutu-Ohwayo (2000) investigated the distribution of fish species in Lake Kyoga along the vegetated margin of the littoral zone, 20 m and 200 m from shore over 12-hour periods to assess how different fish species might be using the littoral zone. They tested the distance from vegetation, dissolved Oxygen and water clarity in structuring the abundance of fish. It was hypothesized that significant differences should exist between cichlids and Nile perch in their distribution because cichlids, in general, have higher tolerance to low Oxygen and are predicted to have higher visual acuity than Nile perch and this could have implications on Nile perch predation of these fishes. The authors (Chandler & Ogutu-Ohwayo, 2000) found that the abundance of Nile perch and some cichlid species along vegetated margins was consistent with the hypothesis that Nile perch are more efficient predators of cichlids in turbid waters. It seemed that the reduction in water clarity in Lake Victoria in 1970s created a cover of darkness that enhanced depletion of the cichlids by Nile perch predation. Protection of littoral vegetation and improvement in water clarity would be beneficial to conservation of biodiversity in those lakes to which Nile perch was introduced.

During the first decades after the introductions, the alien species did not boost the fishery. The introduced tilapiines appeared to compete for spawning sites and nurseries with the native species (Welcomme, 1967; Lowe-McConnell, 1987). Also, hybridisation with the native *Oreochromis* species was observed (Welcomme, 1967; Ogutu-Ohwayo, 1990b).

After the introduction of Nile perch, total fish landings in the Tanzanian waters rose by a factor of three to four, while the standing stock of bottom-dwelling fishes in the Mwanza Gulf dropped by a factor of five to ten (from more than 250 kg ha^{-1} to less than 50 kg hr^{-1}). Similar observations have been made in the Ugandan part of the lake (Okaronon, 1994). For the Nyanza Gulf, where the Nile perch upsurge occurred a couple of years earlier than in other parts of the lake, Moreau (1995) found contradicting results. With the aid of

ECOPATH II, a steady state model of trophic interactions in ecosystems, he estimated that between 1971 (pre-Nile perch) and 1985 (post-Nile perch) the total fish biomass in the Nyanza Gulf increased from 27 tonnes km^{-2} to 43 tonnes km^{-2} (270 kg ha^{-1} to 430 kg ha^{-1}). The large difference for ichthyomass in the post-Nile perch situation obtained by the two methods may have various causes:

1. inaccuracies in landing statistics (CIFA, 1988) and gaps in the knowledge of parameters that were used for ECOPATH II, some of which had to be guessed (Moreau, 1995);
2. the data only refer to bottom-dwelling fish and neglect *Rastrineobola argentea*; or
3. due to a higher swimming speed, the catchability of Nile perch in trawl nets may be lower than that of haplochromines, which would result in an underestimation of the Nile perch stock in the data.

Even if the author compensates for the latter two discrepancies, there are no indications of an increase in the ichthyomass in the Nyanza Gulf in the post-Nile perch system.

2.2. **Food and feeding habits**

Studies on food and feeding of *L. niloticus* have been undertaken in limited areas and time in the Mwanza waters (Goudswaard, 1988; Ligtvoet & Witte, 1991; Mkumbo & Ligtvoet, 1992), the Nyanza and Kavirondo Gulfs (Ogari, 1985; Okemwa, 1986; Hughes, 1986) and the Jinja waters (Ogutu-Ohwayo, 1988, 1990a; Acere, 1988). These researchers made similar observations on shifts in the diet of *L. niloticus*. The early reliance on *Haplochromis* had diminished considerably as this prey species had virtually disappeared. There had been a corresponding increase in the appearance of *Rastrineobola argentea* in the diet and a very rapid growth in the percentage of fish feeding on *Caridina nilotica*. The young *L. niloticus* utilize *Caridina nilotica* as a major food item.

Ogutu-Ohwayo (1985) examined the food of the Nile perch in Lake Kyoga to estimate the extent of predation upon the populations of fish in the lake. Nile perch was observed to feed on invertebrates when young, changing to a piscivorous diet with increasing age. *Rastrineobola argentea* and *O. niloticus* were the most important fish prey with haplochromines and *L. niloticus* forming a less significant contribution to the diet (Ogutu-Ohwayo, 1985). Ogutu-Ohwayo (1985) further observed that since its introduction, the Nile perch had shifted from one type of prey food to another and that cannibalism had increased and the condition factor of the predator had decreased. The author concluded that it appeared the Nile perch had caused considerable damage to the populations of fish in Lake Kyoga and that it was capable of depleting stocks of other fish in a few years.

Acere (1985) reported that during the early part of the first year Nile perch fed on, among other things, prawns, *Caridina*, fish fry and small gastropods and bivalves, and later changed to prey predominantly on haplochromine cichlids and *Rastrineobola* in proportion to their abundance. During the 1981-1985 bottom trawl survey in the Northern portion of the Uganda waters of Lake Victoria, Nile perch extended the range of its major food items to include juveniles of its own and those of *O. niloticus* (Acere, 1988). The predominance of the food item was proportional to its abundance in the habitat and *Caridina* formed a very significant food item in the stomach contents of all sizes of Nile perch caught by bottom trawling.

During the period August 1981-July 1982, *L. niloticus* from bottom trawl survey in the Nyanza Gulf of Lake Victoria fed on fish, insects, crustaceans and molluscs (Ogari, 1985). The post larvae preferred microscopic crustaceans and insects, whereas the juveniles fed mainly on prawn, *Caridina nilotica*. With the increase in size *L. niloticus* became more piscivorous. The type of prey taken depended on both food availability and the size of the predator.

Gut analysis of *O. niloticus* showed the fish does not necessarily choose the most abundant algal species in the water for its food (Njiru *et al.*, 2000a). This observation thus questions the earlier belief that the fish does not select algae because it feeds by gulping water within its vicinity. In the Nyanza Gulf fish fed mostly on blue green algae, though *Microcystis* spp were not preferred. In the open waters, the fish always preferred *Nitzschia acicularis* even in presence of *Anabaena* blooms.

Another study in the Kenyan waters of Lake Victoria revealed that the diet of

O. niloticus was currently more diverse, consisting of insects, fish, algae, plant material, bivalves and invertebrates (Njiru *et al.*, 2000b). Insects mainly *Povilla adusta* and to a less extent *Trichoptera* nymphs, constituted the bulk of the food consumed by the fish throughout the lake. Fish earlier not reported as a major diet for the species featured prominently in the diet. Among the fish encountered in the diet were *L. niloticus, R. argentea, O. niloticus* and haplochromines; the most preferred fish was *R. argentea.* There was no size preference for particular food items although juveniles less than 5 cm fed mainly on cladocerans. Njiru *et al.* (2000 b) argued that the feeding patterns observed in *O. niloticus* may be as a result of the species plasticity and response to changed ecological conditions prevailing in the lake following water hyacinth infestation. Due to this changed feeding behaviour in *O. niloticus*, a new food web was emerging in the lake. They expected that if the present wide spectrum food base of *O. niloticus* continues and proper fishing methods prevail, this fish could easily become the most commercially important in the lake.

2.3. **Age, growth and reproduction**

Acere (1985) studied the age, growth, size at first maturity and sexuality of *Lates niloticus* in the Northern portion of the Uganda waters of Lake Victoria, within the hinterland of Jinja, using data collected from commercial fish landings between 1960 and 1984. He made the following observations:

- Nile perch grow very fast attaining a length of 52 cm TL (mean length of 36.38 cm TL) by the end of the first year of the cohort. Growth rate gradually decreased between year 2 and 5 and then became almost linear up to the observed length (L_∞) of 190 cm TL at age 13+. The maximum asymptotic mean length was 256.69 cm TL, the growth rate (k) was 0.09 and the hypothetical time at which fish would be 0 years old (t_0) was between –1 and –1.09 years.

- *Lates niloticus* exhibited sexual dimorphism and an unequal sex ratio. The males dominated up to 120 cm TL and thereafter the females become more populous than males. The smallest sexually mature individuals observed were 53.5 cm TL male (age 1+) and 67.5 cm TL female (age 1+). By age 2 (>70 cm TL) all Nile perch examined were sexually mature. Older and larger females had significantly larger ovaries. The gonad maturity stages in samples examined varied among size classes, age groups, years sampled and from one time interval to another.

2.4. Environmental degradation

Ochumba (1988) studied fish kills in the Kenyan waters of the lake and observed that although records of fish kills dated back to the 1920s, there was evidence that their frequencies of occurrence had been increasing in recent years. Large fish were mainly affected and although a number of causes had been suggested, the pattern of the kills would suggest massive deoxygenation. The recurrent fish kills of the species *Lates niloticus*, *Oreochromis niloticus* and *Rastrineobola argentea* could be attributed to the dissolved Oxygen depletion due to water movements and the die-offs of the algal blooms.

Data on physical and chemical parameters collected during the period October 1997 to January 2000 with the main objective of relating them to environmental quality and fish survival and catches in the Kenya waters of Lake Victoria revealed that dissolved Oxygen concentrations in areas with water hyacinth infestation were low, of the order 0.84 mg l^{-1}, to 1.5 mg l^{-1} at Awach River mouth (Kenyanya, 2000). Fish catches were low and included *O. niloticus, Protopterus, Clarias*. These are fish that have a high tolerance to low Oxygen concentration.

The rapid increases in Nile perch stocks and depletion of native species were concurrent with changes in physical and chemical conditions and biological characteristics of Lakes Victoria and Kyoga (Ochumba & Kibaara, 1989; Hecky & Bugenyi, 1992; Hecky, 1993; Mugidde, 1992, 1993). There was an increase in nutrient inputs into the lakes, especially from the atmosphere and from changes in land use in the catchment area (Bootsma & Hecky, 1993). Increased inputs of nutrients, especially phosphorus and nitrogen, were recorded in Lake Victoria (Hecky, 1993). This stimulated algal production and led to changes in the taxa of dominant algae. Silicon concentration, which is vital for diatom growth, decreased by a factor of 10 probably due to increased inputs of phosphorus and increased sedimentation of silicon. Consequently, diatom composition changed from dominance of *Melosira* to *Nitzischia*. The decrease in *Melosira*, which was important food for *O. esculentus* (Graham, 1929), may have affected this species and contributed to its disappearance.

In Lake Victoria, Hecky and Bugenyi (1992) observed that sulphate was behaving as a nutrient and deserved serious consideration as a factor limiting phytoplankton and bacterial growth. The P concentrations in 1961 were certainly in excess of those required to support the algal crops observed and were unlikely to limit phytoplankton growth (Talling, 1966). The observed increase in chlorophyll concentrations in Victoria were attributed to an increase in supply of some other nutrients which had increased while P sedimentation accelerated by approximately a factor of 2 during 1961-1988 (Kling *et al.*, 2001). Both nitrogen and sulphur, which are primarily supplied from the atmosphere, were likely candidates. Recent accounts of the degree of atmospheric contamination of Africa from savanna burning (Simons, 1989) may provide a mechanism allowing for increased deposition of Nitrogen (N) and Sulphur (S) to Lake Victoria. An alternative hypothesis would involve changes in the trophic structure of Lake Victoria after the introduction of Nile perch and Nile tilapia (Ogutu-Ohwayo, 1992). If these changes have resulted in reduced herbivory and detritivory and a disruption of the regeneration in Si because of increased sedimentation then similar water quality changes might result. The interaction of the trophic structure with water quality has been hypothesized to lead to a decrease in phytoplankton abundance through a cascade of effects in some lakes. The evidence for increased algal biomass in Lake Victoria is worrisome, especially if it is shown to be lakewide, as the eutrophication could lead to increased Oxygen demand in the lake's deep water and decrease the hypolimnetic volume habitable by fish during seasonal stratification.

Algal biomass is now four to five times higher than the mean values of the 1960s and phytoplankton production has doubled (Mugidde, 1992, 1993). Water transparency has decreased to a quarter of what it was during the 1960s. The algae are dominated by cyanobacteria, which are not readily consumed by fishes, and can also produce phytotoxins, which can be dangerous to aquatic life and degrade domestic use of the water. Decay of the excess organic matter depletes the water column of Oxygen. This has led to development of anoxic water in deepest parts of the lake (>40 m). Oxygen concentration in the hypolimnion during the period of stratification has decreased and anoxia now occurs for longer periods and extends to shallower depths (Hecky, 1993; Hecky *et al.*, 1994). This has reduced habitable space for many fish species and is thought to have accelerated depletion of the deep water haplochromines by confining them to shallower waters where they fell prey to Nile perch (Hecky, 1993).

Although *L. niloticus* is generally a bottom dwelling species, the study observations in the Mwanza Gulf indicated that *L. niloticus* also stays and forages pelagically in water layers of 10-20 m below the surface (Ligtvoet & Mkumbo, 1990). This phenomenon is related to the fact that *L. niloticus* has a relatively high Oxygen demand and that due to stratification, especially in the rainy seasons when there are less strong winds, the Oxygen concentrations are low (often less than 2 ppm) in the lower-most part of the water column

(Wannink, 1988). In these periods the species has to move to the upper water layers. The movement to higher water layers probably also is related to the presence of the pelagic cyprinid *Rastrineobola*, one of its main food items in that area (Wannink, 1988).

It is evident from the above that almost all the research work on the fisheries of Lake Victoria, after the establishment of the Nile perch, has been carried out in limited inshore areas of the lake and for limited periods of time. No studies on the distribution and abundance of *L. niloticus* and *O. niloticus* in the entire lake have been reported. Similarly, no studies linking the fish stocks dynamics directly to environmental and other factors have been reported for Lake Victoria.

This study will update the available information on the status of the stock in Lake Victoria and refine the trends and parameters that were obtained under limited coverage in terms of time and space. This study was done in the Uganda portion of Lake Victoria. Similar studies were being undertaken in the Tanzania and Kenya portions of the lake. All these studies would give the status of the stocks and their dynamics in Lake Victoria as a whole.

CHAPTER 3

3.0. MATERIALS AND METHODS

3.1. Study area

The study was carried out in the Ugandan sector of the lake (Fig. 1) which was divided into 3 zones (Figs. 1 & 2). The three zones are I – Tanzania/Uganda border to Bugoma Channel (Bukakata), II – Bukakata to Rosebury Channel (Kiyindi), and III – Kiyindi to Uganda/Kenya border. These zones were further subdivided into squares (hereafter referred to as grids) based on latitudes and longitudes and measuring approximately 15 nautical miles. A description of the grids surveyed is shown in Table 1 and Fig. 3.

3.2. Collection of data

Data were collected through bottom trawling (for demersal fish), gill netting (for inshore and open waters) and use of appropriate instruments (for environmental and other factors) as outlined below.

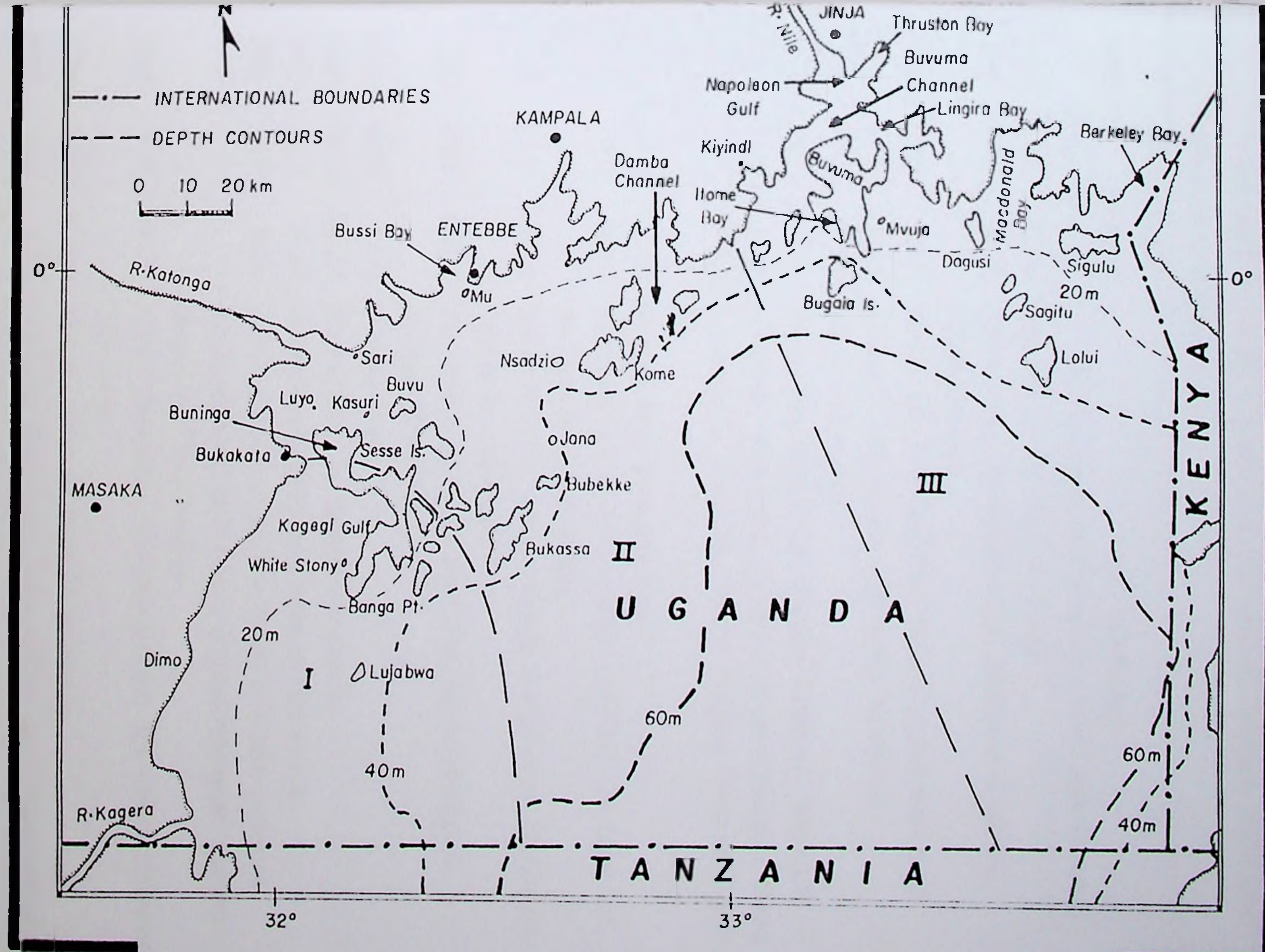


Figure 2. Map of the Uganda sector of Lake Victoria showing sampling zones, depth contours, and major Islands and bays during bottom trawl surveys between January 1999 and December 2000. (Arrows indicate actual location of the named sites, etc)

Table 1. Grids (15x15 nautical miles) surveyed during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Grid	Water Depth (metres) Aver.	Range	Key locations (Is. ≡ Island, Is ≡ Islands, LH ≡ Light House)
A07	11.8	10-14	Napoleon Gulf, Thruston Bay
A08	13.3	8-29	Ekunu Bay, Hannington Bay, Buvuma Channel, Pilkington Bay
B04	10.6	3-27	Bussi Bay, Entebbe Bay (Kitubulu), Kasenyi area
B05	26.2	22-32	Kisima Is., Bulago Is., Zirivandi, Nsadzi Is.
B06	27.8	25-31	Damba Channel
B07	19.9	8-44	Itome Bay, Bugaia Is., Kiyindi, Kibibi Is., Wema Is.
B08	25.5	15-32	Mvuja Is., Kaiyongo, Luvia Is., West of Dagusi, Busiji
B09	18.1	13-26	Luvangu Is., Simu Is., Kazza, Ragwe, West of Sigulu Is.
B10	14.0	5-25	Pringle Bay, Berkeley Bay
C03	9.0	5-25	Rumbwa Is., Buvu Is., Kasuri LH, Sari LH, Luyo LH, Bunjako Bay, Zinga Bay
C04	21.2	9-28	NE of Buvu Is., Mu Is., North of Kitobo Is., Serinya Is., Banda Is., Changu LH
C05	26.6	16-55	Mu-Nsadzi Is, Jana-Nsadzi Is, Kome-Bulago Is, Bulago-Mbazi Is
C07	44.2	31-56	Bugaia-Mwama Is
C09	25.5	24-26	Sagitu-Lolui Is, Sagitu-Masiwa Is
D02	14.3	9-20	White Stony-Bale, Namirembe-Mweza Is
D03	12.6	5-23	Bomangi Bay, Dwavanu-Mweza, Kibibi-Lunguru, Kasai Hills-White Stony, Lunguru-Kasakah, Lambu-Bugoma. William's Bay
D04	23.6	14-27	Kitobo-Nzirwe Is, Lutoboka Chan.-Bukone Is., Kawari-Nzirwe Is
D05	40.8	34-48	Nzirwe-Jana Is, Jana-Rwamfua Is
E02	15.6	7-23	Bunyaga Bay-Dimo, Dimo-Linga, Dimo-Masambwa Is, Bale-Namirembe
E03	30.5	21-35	Lujabwa Is.-Linga Pt, Linga- Banga, Linga-White Stony
F02	19.6	15-25	Dimo-Masambwa Is., Sango Bay, Masambwa Is.-Chawasimba, Masambwa-Lujabwa Is

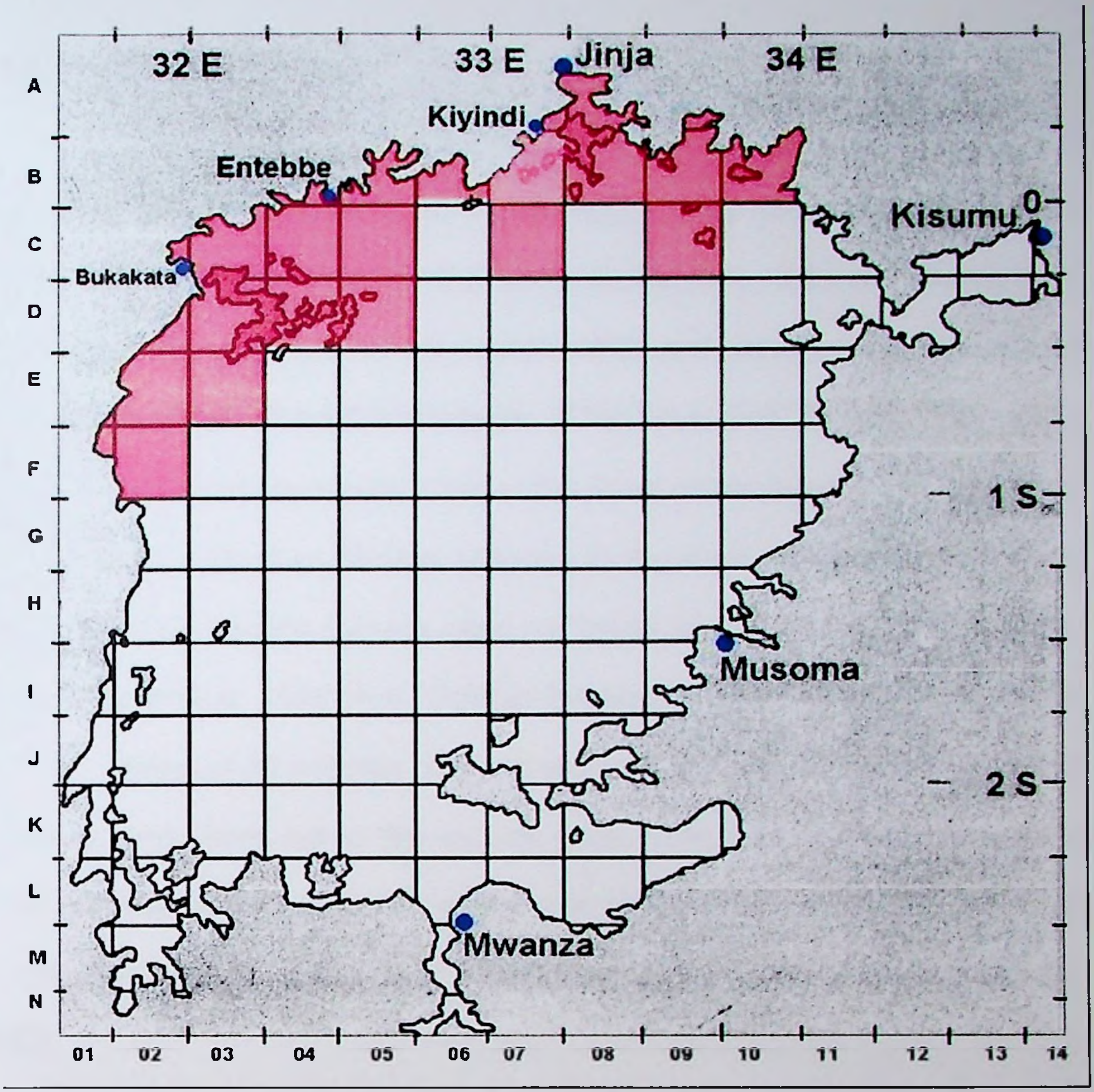


Fig 3: Map of Lake Victoria showing the grids (15x15 miles) sampled (Red shading) in the Ugandan sector during bottom trawl surveys between January 1999 and December 2000.

[See Table 1 for summary information on the grids surveyed]

3.2.1. **Collection of fish data**

3.2.1.1. Bottom trawling

Experimental bottom trawling surveys, each lasting about 10 days, were carried out within the grids monthly between January 1999 and September 2000, thereafter quarterly in December 2000 and March 2001, using the Uganda Fisheries Research Institute (FIRI) research vessel R.V. IBIS. Attempts were made to survey each of the three zones once every quarter to take account of the four climatic seasons in the area; these were achieved except for Zone I where surveys were not made during January-March 1999, October-December 1999 and October-December 2000 because of harsh weather. Hauls of 30 minutes duration were taken using a 25.4 mm codend stretched mesh trawl net in the various grids. The grids surveyed included those with transects surveyed in earlier operations (1981-1998) (Okaronon *et al.*, 1985; Okaronon & Kamanyi, 1986; Okaronon, 1994; Okaronon *et al.*, 1999).

The trawl net used was a large wide-mouthed net dragged along the lake-bottom by the 180 hp research vessel R.V. IBIS that is 17 metres long and has a 4.9 metres beam and a 2.4 metres draft. The trawl net had a head rope (where the floats are attached) of 24 metres length and a footrope (where the chains or sinkers are attached) of about 28 metres length. The depth/opening of the net was estimated at 1.5 metres. The codend, i.e. the closed bag part of the net, was fixed to the end of the net. The trawling speed was maintained at about 3 knots.

Fish catches were sorted into species (Plates 3 & 4). 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 weights were taken using 100-kg Salter weighing balance for fish >10 kg weight, 10-kg Top-Loading balance for fish 1-10 kg and 1-kg spring balance for fish weighing <1 kg. The lengths are in centimetres (cm) to the nearest millimetre (mm), using a measuring board.

For large quantities of fish retained, subsampling 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) – containing about 200 fish - was taken and analysed for individual lengths and/or weights and the results raised accordingly.

The routine information also recorded for each haul included date, haul number (serial), grid (box number), location, time (start and end), course, water depth (start and end), warp length, codend mesh, weather.

Of the 490 hauls made from January 1999 to December 2000, 44.1% were taken in Zone II, 37.5% in Zone III and 18.4% in Zone I (Table 2). The low numbers of hauls in Zone I was primarily because of breakdown of the

Plate 3. Research Vessel IBIS used during bottom trawl survey of Uganda waters of Lake Victoria between January 1999 and December 2000

Plate 4. Catch of fish being hauled, in a trawl net, after fishing/trawling for 30 minutes.

Plate 5. Fish catch from the trawl net, dominated by *Lates niloticus* (Nile perch)

research vessel and, to a certain extent, rough weather. The majority of the trawl hauls (69%) were made in waters between 10 m and 30 m deep, while 21.2% were in shallower waters (<10 m deep) and 9.8% in waters deeper than 30 m. Most of the bottom waters deeper than 30 m were anoxic and trawl hauls from these waters often had no fish catch.

The survey covered all the three zones and water depths 4-60 m in these zones; this was to enable the assessment of the fish distribution patterns by water depth, zones and grids/habitats. The water stratum of 60-84 m deep could not be surveyed because the warp length required was greater than the 300 m that the vessel winch drum accommodated. The trawl hauls were taken for a constant duration of time (30 minutes) and a constant speed (3 knots) so as to provide a constant 'swept area' on which to base estimation of abundance. Also, the survey covered various water depths and seasons to take account of the variation in fish abundance in these areas, grids/habitats and seasons. A 25.4 mm codend stretched mesh trawl net was used to enable capture of all sizes of fish.

Table 2: Distribution of hauls during bottom trawl surveys in the various depth ranges in the Uganda sector of Lake Victoria between January 1999 1nd December 2000.

Period	Water Depth Interval (metres)														
	Zone I					Zone II					Zone III				
	4-10	10-20	20-30	30-40	40-50	4-10	10-20	20-30	30-40	40-50	4-10	10-20	20-30	30-40	40-50
1999 January											3	10	18		1
March						6	13	5	3						
April		4				9	9	10	4	1					
May											3	6	7	3	
June						12	10	12	3	1					
July			2	3											
August											1	12	1	1	
September	3	5	8			1	2								
November						7	6	9	2	1					
December											6	20	11		1
2000 February	1	5	2	5		4	5	4	3			2			
March		11	7	2		2	2								
April	3	7	2	3			2				2				
May						3	4	8			1	2			
June											6	13	7		2
July	1	2				10	6	4	1			3	1		
August											3	15	5	1	2
September	2	7	1	4		8	4	6	1		1				
December						5	4	4			1	8	5		
Total	10	41	22	17		67	67	62	17	3	27	91	55	5	6
Total by zone			90					216					184		
Total for Uganda sector								490							
Percentage by zone			18.37					44.08					37.55		

3.2.1.2. Gill netting

Due to limited possibilities of trawling in shallow (<4 m deep) water – because of the draft of the vessel of 2.4 m -, gill nets were used to sample such habitats. In addition, multi-mesh monofilament gill net surveys were conducted in the open deep waters along the bottom trawl surveys during November and December 1999; this was aimed at determining the distribution of the fish in the water column.

In the shallow inshore waters, the surveys were conducted in the Napoleon Gulf, Fielding Bay and MacDonald Bay (Fig. 4) during April and September 2000 and February, May, June/July and July/August 2001; in the Entebbe waters of the lake, the surveys were conducted during May and October 2000 and April, July and September 2001.

Fleets of nets, each consisting of 10 panels of netting, were used; each panel was 15 metres hung length (hanging ratio of 0.67) and 5 metres depth. The panels were of mesh sizes 30, 38, 48, 60, 77, 97, 124, 157, 199 and 252 mm, and were distributed randomly along each fleet. In the open deep waters, up to 4 panels of netting were set from the water surface to the lakebed (Fig. 5). In the shallow inshore areas, however, single panels were used. The nets were set during the day, for a period of 6 hours. In the open deep waters, gill netting was conducted in one of the grids trawled that day. The fish retained were sorted by mesh size. Information from these fish included species, length, weight, sex, gonad condition and stomach contents.

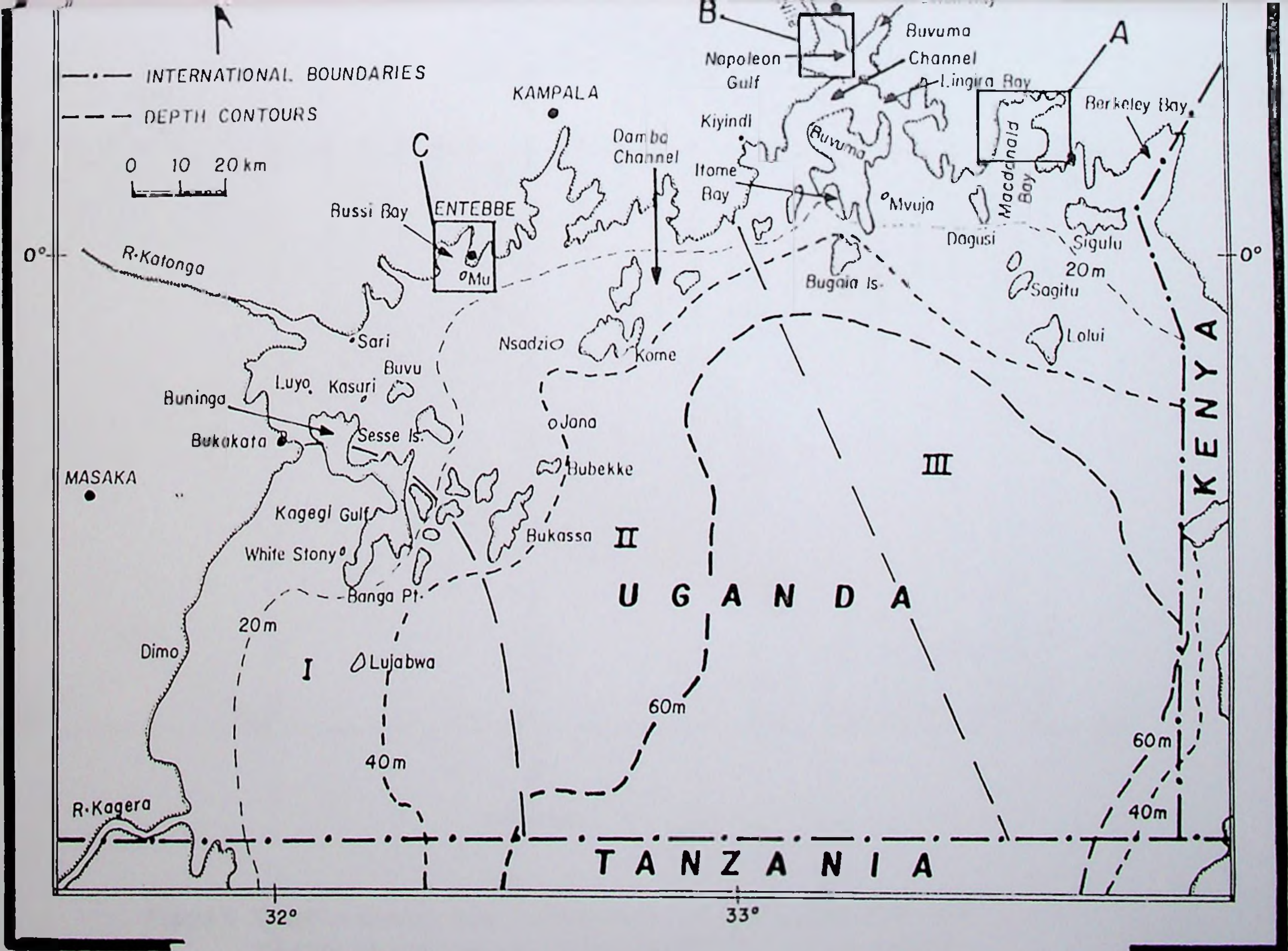


Figure 4. Sampling areas for multi-mesh monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001: (A) MacDonald Bay, (B) Napoleon Gulf and Fielding Bay and (C) Entebbe area.

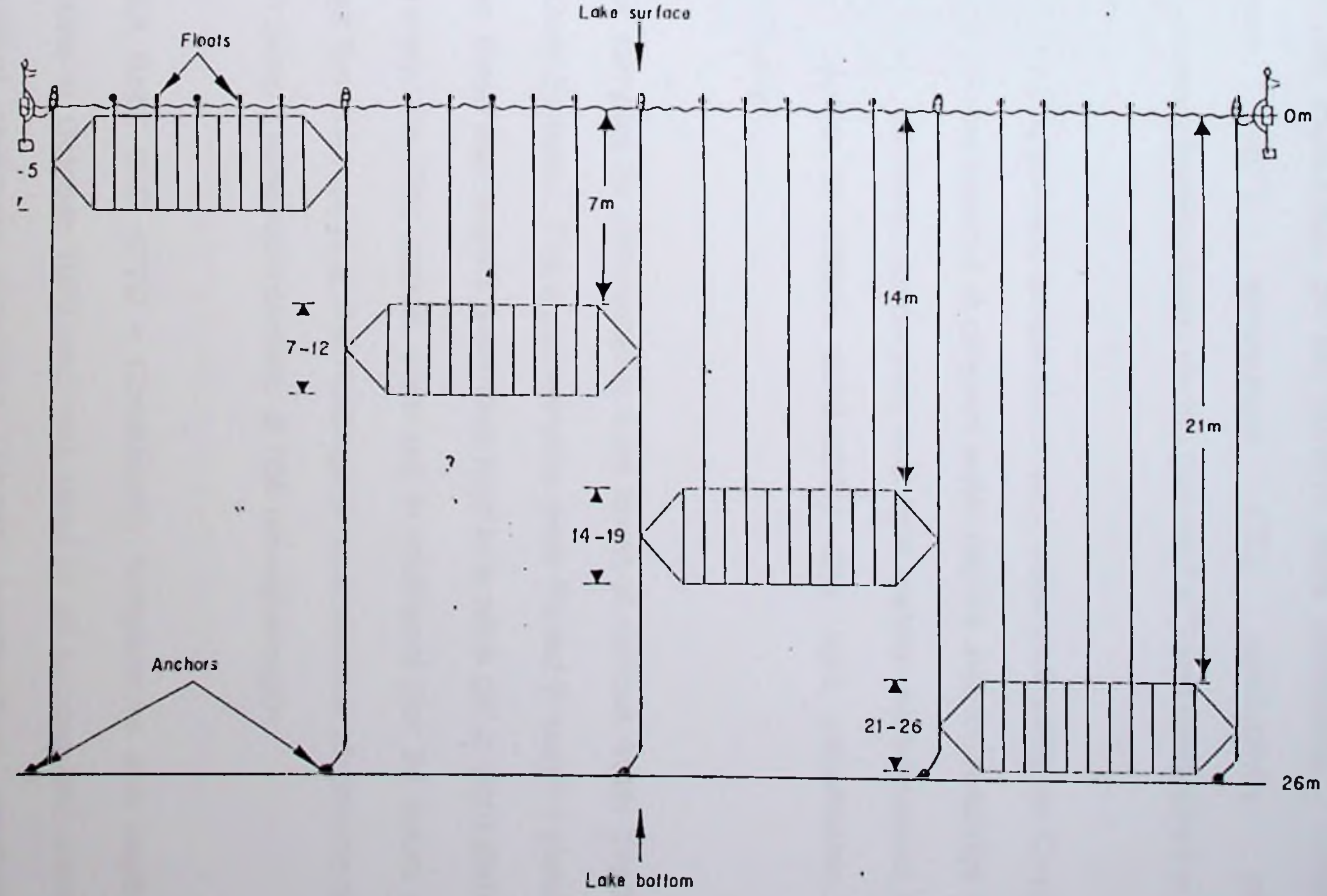


Figure 5. Diagram showing how the multi-mesh monofilament gill nets were set over the water column in the Uganda sector of Lake Victoria between April 2000 to September 2001.

3.2.2. Collection of environmental data

Limnological parameters were taken and recorded in the areas where bottom trawl and multi-mesh gill net surveys were conducted. These included Oxygen (mgl^{-1}), temperature (°C), conductivity, pH, light transparency/turbidity/water clarity) ($\mu m\ cm^{-2}\ s^{-1}$) and chlorophyll-a ($\mu g\ l^{-1}$).

Dissolved Oxygen and temperature were measured using an Oxygen meter. The meter was lowered at different water depths and the readings taken from the meter. Similarly, conductivity and light meters were lowered at different water depths to obtain conductivity and light penetration readings, respectively.

Water samples for chlorophyll-a were taken at various water depths using a van Dorn Sampler. The water samples were filtered through a glass fibre filter paper; these filter papers were then kept in a silica gel in petri dishes. In the laboratory, the filter papers were put in methanol (for 24 hours at 5°C) to extract the chlorophyll a; the readings (concentrations of chlorophyll-a) were taken using a spectrophotometer at 665 nm wavelength.

A SEA BIRD CTD (CTD = Conductivity, temperature and depth) became available in October 1999 and was used in all subsequent surveys. This instrument measures dissolved Oxygen, temperature, conductivity, and chlorophyll-a at various water depths.

3.3. ***Data analysis***

Appropriate computer programs (MICROSOFT EXCEL and FISAT) were used to analyse the data to obtain the required information on the expected outputs.

The fish data collected through bottom trawl and gill net surveys were analysed for the following parameters: species composition and distribution, abundance by water depth and season, stock biomass trends (for trawl data only), and stock population structure. The chi-square (X^2).test was used to test the observed sex ratios of *L. niloticus* and *O. niloticus* for the significant differences from the theoretical ratios.

Length frequency data from bottom trawl surveys were used to obtain the following parameters for *L. niloticus* and *O. niloticus*: growth rates [length at infinity (L_∞) and growth rate (K)], size at maturity (first and 50%), mortality rates [total mortality (Z), fishing mortality (F)) and (exploitation rate (E)] and recruitment patterns. Gut contents for *L. niloticus*, collected from bottom trawl surveys, were analysed for: food items ingested (referred to as diet) and shift in diet with season, age and zone/water depth.

Data on limnological and other factors were analysed and trends in fish data by grids and water depth were compared with patterns generated by limnological data.

3.3.1. **Estimation of fish abundance and stock biomass**

The swept area (A_{sw}) method (Sparre & 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 & van Densen, 1995)

xe is the catch efficiency, 1

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).

$$\text{Standing crop=CPUA=}W_{mean}/(A_{sw}*vi)$$

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 (ASILA, pers. Commun.). This accounts for the vertical movement of round fish like *L. niloticus*, which are well known to rise in search of, prey from time to time.

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 study the estimates have been obtained by water depth intervals.

3.3.2. Estimation of biological parameters

In order to understand the fish population dynamics of *L. niloticus* and *O. niloticus*, several fish parameters have to be known. These are growth, reproduction, mortality, recruitment and feeding.

3.3.2.1. *Estimation of growth parameters*

Data analysis was based on length frequency distributions using the Electronic Length Frequency Analysis (ELEFAN 1) routine of the FAO-ICLARM Stock Assessment Tools (FISAT) program. The estimation of the growth parameters was based on the von Bertalanffy growth model expressed in the form:

$$L_t=L_\infty(1-\exp(-K^*(t-Kt_0)))$$

where L_t is the predicted length at age; L_∞ is the asymptotic length or the maximum length the fish of a given stock would reach if they were to grow indefinitely; K is the growth coefficient and t_0 is the age the fish would have been at zero length.

The asymptotic length (L_∞) and growth coefficient (K) were estimated using Response analysis in the FISAT program.

3.3.2.2. ***Estimation of size at maturity***

Aspects of the reproductive biology of fishes were assessed from monthly samples from trawl catches. For each fish, total length (TL) for Nile perch, *L. niloticus*, and Nile tilapia, *O. niloticus*, (nearest cm) and total weight (g) were measured. Each fish was opened and the maturity stages assigned using the classification described in Table 3, which was modified from Nikolski (1963).

Length frequency measurements were taken for mature (maturity stage IV and above) and immature male and female fish. Regression analysis was carried out for proportion of fish mature against the total and the L_{m50} (size at 50% maturity) was determined by SOLVER, an MS Excel sub-routine, which fits a sigmoid curve through a data set ranging from zero mature fish to all mature fish.

'3.3.2.3. ***Estimation of mortality rates***

The total mortality rate (*Z*) was estimated using the linearised length – converted catch curve (Pauly, 1980, 1984) in FISAT, with the growth parameters from the von Bertalanffy as input data.

Natural mortality (*M*) was estimated with Pauly's (1980) empirical formula linking natural mortality with the von Bertalanffy parameters (K - yr^{-1}), L_∞ (cm) and mean annual water temperature (T - °C). An average temperature of 25°C was used for the estimate of *M*.

Table 3. Gonad maturity stages in fish from Lake Victoria

	Stage	General	Males	Females
I	Immature	Young individuals which have not yet engaged in reproduction, young small sexual organs close under vertebral column; gonad of very small size.	Transparent, colourless to grey	Eggs invisible to naked eye.
II	Resting	Sexual products have not yet begun to develop; gonads of very small size.	Underdeveloped, small, translucent.	None visible to naked eye.
III	Developing	Ovary/testes occupy about half of ventral cavity.	Opaque, reddish with blood capillaries.	Eggs visible and opaque, appear as whitish granular.
IV	Ripe (Mature)	Sexual products ripe, sexual organs filling ventral cavity but the sexual products are still not extruded when light pressure is applied.	Fills body cavity.	Translucent, large and round.
V	Spawning	Sexual products are extruded in response to very light pressure on the belly	Release eggs/milt when pressed	Large translucent, some free in ovary.
VI	Spent	Sexual products have been discharged, genital aperture inflamed, gonads have the appearance of deflated sacs.	Shrinking slack, the ovaries usually containing a few left over eggs and the testes some residual sperm.	Some residual eggs.

Fishing mortality (F) was computed from the relation $Z=F+M$, while the exploitation rate (E) was calculated from $E=F/Z=F/(F+M)$. The total mortality rate (Z) was estimated using the linearised length–converted catch curve (Pauly, 1980, 1984), with the growth parameters from the von Bertalanffy as input data.

The catch curve was obtained by plotting the natural logarithms of the numbers of fish surviving by length:

$$\ln(N_{(L1-L2)}/dt)=\text{constant}-Zt_{(L1+L2)}/2 \quad \text{or} \quad \ln(N/dt)=\text{constant}-Zt$$

where, N is the number of individuals in each age and, t is relative age. The value of dt is the time taken for the species to grow through a particular length class.

The inputs included monthly length frequency data (January 1999 to December 2000) with constant class size of 3 cm total length, length at infinity (L_∞), growth rate (K) and mean annual habitat temperature (T in °C). The inputs to the yield-per-recruit model with knife-edge selection were as follows: (1) *L. niloticus*: L_∞ = 256 cm YL, K = 0.29 yr^{-1}, T=25°C and (2) *O. niloticus:* L_∞ =75 cm TL, K = 0.40 yr^{-1}, T=25°C.

3.3.2.4. ***Estimation of recruitment patterns***

The recruitment pattern was obtained by using FISAT, from a time series of length frequency data, to determine the number of pulses per year and the relative strength of each pulse. Recruits are fully metamorphosed young fish whose growth can be described by the von Bertalanffy growth model, and are fish occurring on the fishing grounds. Relative yield per recruit (*Y'/R*) analysis is used to assess the effect of different exploitation rates on a fishery (Sparre & Venema, 1998). Management advice is most often based on relative yield.

Relative yield-per-recruit (Y'/R) analysis was based on the Beverton and Holt model of 1966, modified by Pauly and Soriano (1986), assuming a knife-edge selection. The inputs included monthly length frequency data (January 1999 to December 2000) with constant class size of 3 cm total length, length at infinity (L_∞), growth rate (K), L_c/L_∞ ratio and M/K ratio,

Where L_c = length at first capture and M = natural mortality.

The relative yield- per-recruit (*Y'/R)* was computed from:

$$Y/R=EU^{MK}(1-(3U/(1+M))+(3U^2/(1+2M))U^3/(1+3M))$$

where: $U=1-(Lc/L_\infty)$=length of fish at first capture; $M=(1-E)/(M/K)=(K/Z)$ and $E=F/Z$.

Relative biomass-per-recruit (*B'/R)* was estimated from:

$$B'/R=(Y'/R)/F$$

while *E* (exploitation rate), $E_{0\cdot1}$ (exploitation rate at which the marginal increase in relative yield-per-recruit is 10% of its value at E=0) and $E_{0\cdot5}$ (value of E under which the stock has been reduced to 50% of its unexploited biomass) were estimated using FiSAT based on the first derivatives of this function. The inputs to the yield-per-recruit model with knife-edge selection were as follows: (1) *L. niloticus*: L_∞ = 256 cm YL, K = 0.29 yr^{-1}, M = 0.42 yr^{-1}, L_c/L_∞= 0.05, M/K = 1.44 and (2) O. *niloticus:* L_∞ =75 cm TL, K = 0.40 yr^{-1}, M = 0.72 yr^{-1}, L_c/L_∞ = 0.050, M/K = 1.8

3.3.3. **The chi-square test**.

The chi-square (X^2) test was used to test the observed sex ratios of *L. niloticus* and *O. niloticus* for the significant differences with the expected or theoretical ratios. In the test, the difference between the observed and expected ratio is squared and divided by the expected ratio.

$$X2 = (O - E) / E$$

where O = the observed ratio and E = the expected ratio.

These test were made for differences between the grid/habitats for bottom trawl data; monofilament data was used to test the differences between the sampling areas.

3.3.4. **Food and feeding habits**

The stomach contents were examined by eye. The food items were sorted into categories and identified. The items were assessed according to size of the fish, season and location (grid).

The data on items ingested were analysed using the frequency of occurrence method. This was done for the various sizes of fish caught and for the different locations (grids) where the fish were caught.

CHAPTER 4

4.0. RESULTS

4.1. Fish species composition and distribution

4.1.1. Fish species composition and distribution in bottom trawl surveys

During the bottom trawl surveys of January 1999 to December 2000, 17 species groups (14 genera) were encountered, namely *Aethiomastacembelus frenatus* (Boulenger, 1901), *Bagrus docmak* (Forskal, 1775), *Barbus* spp, *Brycinus* spp, *Clarias gariepinus* (Burchell, 1815), *Haplochromis* spp, *Labeo victorianus* Boulenger 1901, *Lates niloticus* (Linnaeus, 1758), *Mormyrus kannume* Forsskal 1775, *Oreochromis leucostictus* (Trewavas, 1933), *O. niloticus* (Linnaeus, 1767), *Protopterus aethiopicus* Heckel 1851, *Schilbe intermedius* (Linnaeus, 1758), *Synodontis afrofischeri* (Hilgendorf, 1888), *S. victoriae* (Boulenger, 1906), *Tilapia rendalli* (Boulenger, 1896) and *T. zillii* (Gervais, 1848) (Appendices 2 & 3). *Lates niloticus* dominated the catches (86.5% by weight) followed by *Oreochromis niloticus* (9.8%) and haplochromines (3.4%); all other species together contributed about 0.3% (Table 4).

Species diversity was greatest in the depth range 10-20 m, and declined markedly with increasing water depth (Table 4). A high proportion of the fish

(92.2%) was found in waters <30 m deep (Table 4). *L. niloticus* and haplochromines occurred in all areas sampled while *O. niloticus* and other tilapiines were restricted to waters less than 20 m deep (Table 4). Few fish were caught in waters of depths greater than 40 m, and these were restricted to *L. niloticus*, haplochromines and *Barbus* spp. The highest catches were obtained in Zone I, where a mean catch rate of 319.7±24.3 kg hr^{-1} was estimated, followed by Zone II (246.3±11.1 kg hr^{-1}) and Zone III (200.2±13.5 kg hr^{-1}) (Table 5). The corresponding figures for *L. niloticus* in Zones I, II and III were 302.0±24.4 kg hr^{-1}, 194.1±10.1 kg hr^{-1} and 183.2± kg hr^{-1}, respectively, while those for *O. niloticus* were 12.4±6.4 kg hr^{-1}, 39.4±9.6 kg hr^{-1} and 11.1±3.2 kg hr^{-1}, respectively (Table 5).

During 1999, the catches of *L. niloticus* in all zones combined ranged from 8.6±0.9 tonnes km^{-2} to 11.5±1.4 tonnes km^{-2} (Table 6). In 2000, however, higher catches of *L. niloticus* were obtained during the rainy periods of March-May (11.6±2.1 tonnes km^{-2}) and August-November (11.6±1.4 t km^{-2}) (Table 6); the catches during the dry seasons were 7.5±1.5 t km^{-2} in December-February and 8.4±2.1 t km^{-2} in June-July. Similar trends were estimated in the 3 zones separately, although the highest catch of 19.8±5.7 t km^{-2} for *L. niloticus* was estimated in Zone I during the period December 1999-February 2000. The catches of *O. niloticus* were highest in June-July during both 1999 (1.2±1.8 t km^{-2}) and 2000 (2.2±1.3 t km^{-2}) (Table 6).

Table 4. Mean catch rates (kg hr^{-1}) by water depth for fish caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

	Water Depth Interval (metres)							
Fish species	4-10	10-20	20-30	30-40	40-50	50-60	Overall mean	%
Lates niloticus	214.4	165.2	274.5	223.6	11.5	0.2	207.6	86.5
Oreochromis niloticus	67.6	22.7					23.6	9.8
Haplochromis spp.	6.6	7.4	12.2	3.9	1.3	1.6	8.2	3.4
Other species	2.1	0.7	0.1	0.1	0.3		0.7	0.3
Number of species caught	11	13	5	3	4	2	17	
Mean of total catch rate	290.7	196.0	286.8	227.6	13.0	1.7	240.1	
95% confidence level	±50.1	±31.3	±59.1	±71.5	±13.5	±7.1	±24.3	
Number of hauls	104	199	139	39	9	3	493	

Table 5. Mean catch rates (kg hr^{-1}) by zone for fish caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
[Mean catch rates plus/minus 95% confidence limits]

	Mean catch rates (kg hr^{-1}) by Zone			
Fish species	Zone I	Zone II	Zone III	ALL Zones
Lates niloticus	302.0±24.4	194.1±10.1	183.2±12.4	207.6±8.0
Oreochromis niloticus	12.4±6.4	39.4±9.6	11.1±3.2	23.6±7.1
Haplochromis spp.	5.2±1.3	12.4±2.1	4.4±0.9	8.2±1.0
Other species	0.1±0.1	0.4±0.1	1.5±0.3	0.7±0.2
Number of species caught	7	13	11	17
Mean of total catch rate	319.7	246.3	200.2	240.1
95% confidence level	±24.3	±11.1	±13.5	±8.6
Number of hauls	90	216	184	490

Table 6 . Standing crop (tonnes km^{-2}±S.E.) of fish caught (by season) during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000. [S.E. = Standard error of the mean] {Seasons: 1=December-February (dry), 2=March-May (rainy), 3=June-July (dry), 4=August-November (rainy)}

			Standing crop (tonnes km^{-2}±S.E.)			
Fish species	Year	Season	Zone I	Zone II	Zone III	ALL Zones
All species	1999	1	5.3±1.1	9.6±1.5	13.1±2.5	10.1±1.3
		2		9.3±0.9	10.3±3.1	9.5±1.0
		3	2.0±0.7	16.0±2.4	11.9±2.0	13.0±2.4
		4	10.0±1.7	15.5±2.8	7.8±2.6	13.7±1.7
	2000	1	20.3±5.6	5.7±1.5	5.6±1.5	8.4±1.5
		2	17.4±3.2	6.1±1.1	9.3±6.6	12.9±2.1
		3	6.5±0.1	14.2±4.0	9.9±2.2	11.0±2.1
		4	13.4±4.2	13.0±1.8	11.7±2.3	13.2±1.5
Lates niloticus	1999	1	5.1±1.1	9.2±1.4	12.8±2.5	9.8±1.3
		2		8.3±0.8	9.5±2.9	8.6±0.9
		3	2.0±0.7	15.1±2.5	7.4±1.5	10.6±1.8
		4	9.5±1.7	12.4±2.3	7.4±2.5	11.5±1.4
	2000	1	19.8±5.7	4.0±1.0	5.1±1.4	7.5±1.5
		2	16.4±3.2	4.6±1.1	1.0±6.2	11.6±2.1
		3	5.9±0.3	7.5±2.5	8.4±2.1	8.4±1.5
		4	12.0±3.8	11.4±1.8	10.8±2.3	11.6±1.4
Oreochromis niloticus	1999	1	0.04±0.1	0.1±0.1	0.2±0.4	0.1±0.1
		2		0.7±0.1	0.1±0.2	0.6±0.2
		3	0.0±0.0	0.4±0.2	4.1±1.5	1.2±1.8
		4	0.3±0.2	0.9±0.4	0.3±0.2	0.7±0.2
	2000	1	0.3±0.2	1.3±0.6	0.4±0.3	0.6±0.2
		2	0.6±0.3	1.0±0.3	1.5±1.0	0.8±0.2
		3	0.3±0.2	6.3±3.0	0.7±0.4	2.2±1.3
		4	1.4±0.8	1.3±0.5	0.6±0.3	1.3±0.3

Based on the length frequency analysis of 291 683 *L. niloticus* caught in bottom trawl during 1999 and 2000, the average size increased with increasing water depth (Table 7). During 1999/2000 the fish caught in Zone I were on average bigger (28.7 (22)) cm total length (modal Length in bracket)) than those from Zones II and III which averaged 15.7 (7) and 14.3 (7) cm total length, respectively; the average for the Uganda sector was 17.8 (7) cm (Table 7). In 1999 the fish averaged 15.5 (7) cm total length in the sector while the fish from Zones I, II and III were 19.3 (7), 15.9 (7) and 14.9 (7) cm average total length, respectively. The fish caught during 2000 averaged 21.1 (7) cm total length in the sector while fish from Zones I, II and III averaged 29.6 (22), 15.0 (7) and 13.2 (5) cm total length, respectively. However, fish from the 4-10 m depth area in Zone I were bigger than the average for the zone (19.3 (7) cm total length)) during 1999 when the fish averaged 21.0 (5) cm total length (Table 7).

4.1.1.1. ***Distribution of the small fish***

The numerical length frequency distribution for *L. niloticus* in bottom trawl surveys in the Uganda sector of Lake Victoria is shown in Figures 6, 7, 8 (details of data in Appendices 4, 5, 6). There was no segregation of fish sizes as both juveniles and adults were caught in all areas surveyed. However, the proportion of juvenile fish less than 6 cm total length decreased with increasing water depth. During 1999/2000 this group of juvenile fish (1-5 cm total length) comprised about 8% of the catch in the Uganda sector of the lake and declined from 14.2% in the 4-10 m depth area to about 3% in the 30-40 m

Table 7. Length frequency distribution for *Lates niloticus* by zone and water depth during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
(TL = Total length (cm)) . [Number of fish in brackets after modal TL]

		Water Depth Interval (metres)				
Year	Zone	4-10	10-20	20-30	30-40	4-40
1999	I Average TL	21.0	19.3	19.2	20.5	19.3
	Modal TL	5 (357)	7 (638)	7 (4078)	7 (221)	7 (5289)
	II Average TL	14.5	15.0	16.6	25.2	15.9
	Modal TL	5 (29190)	6 (32130)	7 (25352)	17 (5046)	7 (91716)
	III Average TL	14.9	13.5	17.4	14.2	14.9
	Modal TL	9 (15880)	7 (36158)	10 (20791)	6 (2648)	7 (75447)
	I-III Average TL	14.6	14.3	17.1	21.4	15.5
	Modal TL	7 (45427)	7 (68921)	10 (50221)	7 (7915)	7 (172484)
2000	I Average TL	23.1	18.2	34.4	21.6	29.6
	Modal TL	36 (906)	7 (11708)	22 (36340)	13 (5337)	22 (54289)
	II Average TL	13.3	15.0	20.3	28.3	15.0
	Modal TL	7 (15511)	5 (7861)	7 (3567)	39 (511)	7 (27450)
	III Average TL	14.6	18.4	27.1	29.1	13.2
	Modal TL	5 (19437)	7 (16672)	13 (1316)	21 (35)	5 (37460)
	I-III Average TL	14.5	13.9	32.9	22.2	21.1
	Modal TL	5 (35954)	7 (36239)	22 (41223)	13 (5887)	7 (119199)
1999/	I Average TL	30.4	18.3	32.9	21.5	28.7
2000	Modal TL	36 (1263)	7 (12339)	22 (40418)	13 (5558)	22 (59578)
	II Average TL	14.1	15.0	17.1	25.6	15.7
	Modal TL	7 (44701)	6 (39991)	7 (28919)	17 (5557)	7 (119168)
	III Average TL	14.7	12.5	18.0	14.4	14.3
	Modal TL	9 (35317)	7 (52830)	12 (22107)	6 (2883)	7 (112937)
	I-III Average TL	14.6	14.2	24.3	21.7	17.8
	Modal TL	7 (81281)	7 (105160)	7 (91444)	10 (13798)	7 (291683)

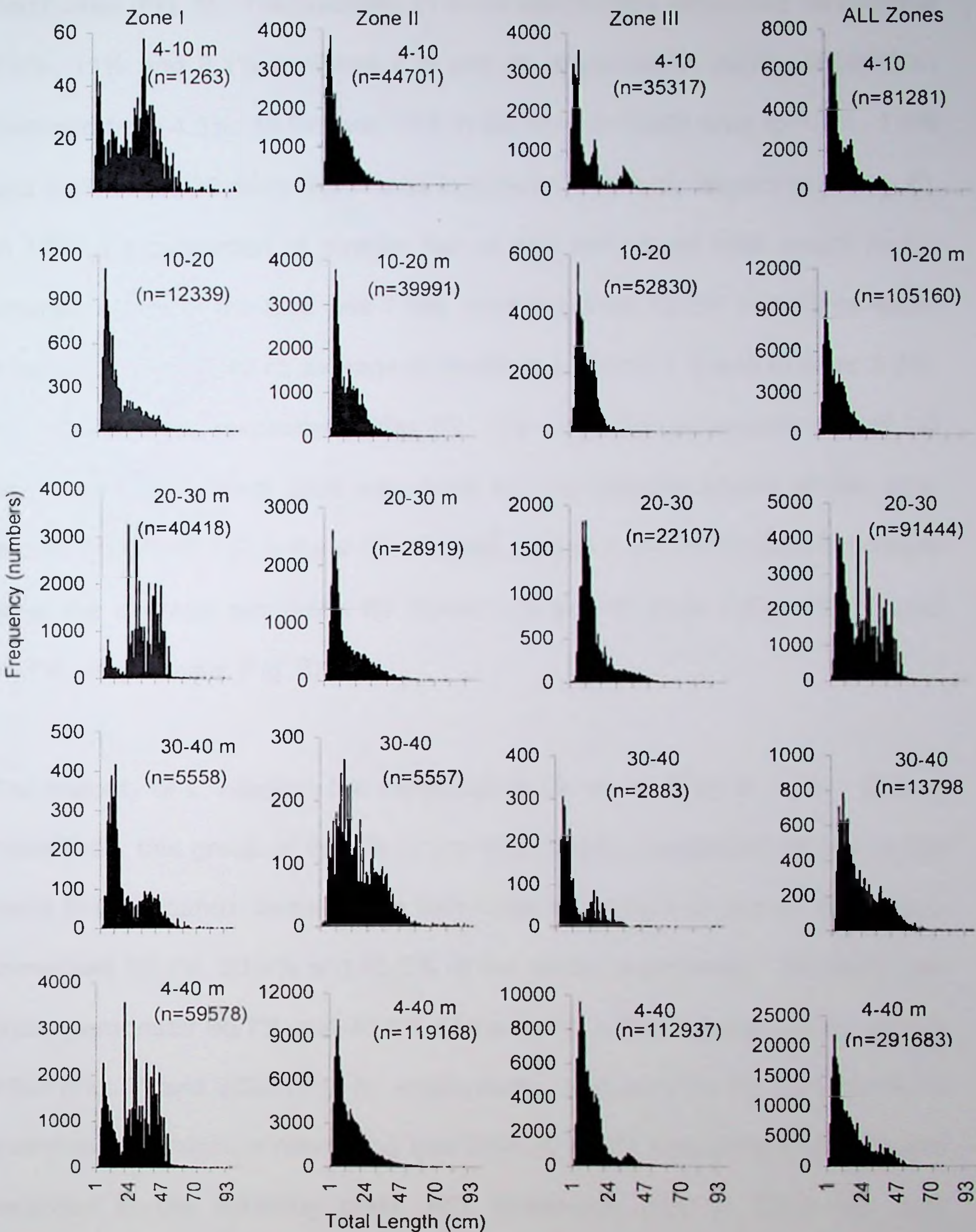


Fig. 6. Length frequency distribution for *Lates niloticus* caught during bottom trawl surveys in the different zones and water depth ranges in the Uganda sector of Lake Victoria between January 1999 and December 2000. (n = number of fish specimens)

depth area (Fig. 6). The juveniles (1-5 cm total length) comprised on average 1.9%, 11% and 8.1% in Zones I, II and III, respectively, during 1999/2000, declining from 4.8%, 14.6% and 14% in the 4-10 m depth area to 1.7%, 1.1% and 9.5% in the 30-40 m depth area in Zones I, II and III, respectively (Fig. 6). In 1999 the proportion of juvenile fish of less than 6 cm total length in the Uganda sector of the lake was 7.8%, declining from 12.2% in 4-10 m depth area to 4.3% in 30-40 m; average proportions in Zones I, II and III were 5.6%, 10.7% and 4.4%, respectively (Fig. 7). The proportion of juvenile fish of 1-5 cm total length during 2000 was 8.3% for the Uganda sector of the lake, declining from 16.7% in the 4-10 m depth area to 1.3% in the 30-40 m depth area; the average proportion for Zones I, II and III were 1.6%, 11.9% and 15.7%, respectively (Fig. 8).

The majority of *L. niloticus* fish measured 6-19 cm TL (Figs 6, 7, 8). During 1999/2000, this group of fish (6-19 cm total length) composed 58.5% of the catch in the Uganda sector of the lake while in Zones I, II and III, this group comprised 25.3%, 60.9% and 73.5% of the catch, respectively. Similarly, the group comprised 66.7% and 45.6% of the catch in the Uganda sector during 1999 (Fig. 7) and 2000 (Fig. 8), respectively. Between 80.7% and 89.4% of juveniles of *L. niloticus* measuring less than 20 cm TL (weighing <100 g) were recorded in the following grids: A07 (Napoleon Gulf in Zone III), A08 (Lingira/Ekunu Bay in Zone III), B04 (Bussi Bay, west of Entebbe Airport in Zone II), B07 (Itome Bay in Zone III), B08 (Mvuja Island area – west of Luvia and Dagusi Islands in Zone III), B09 (Luvangu-Sigulu

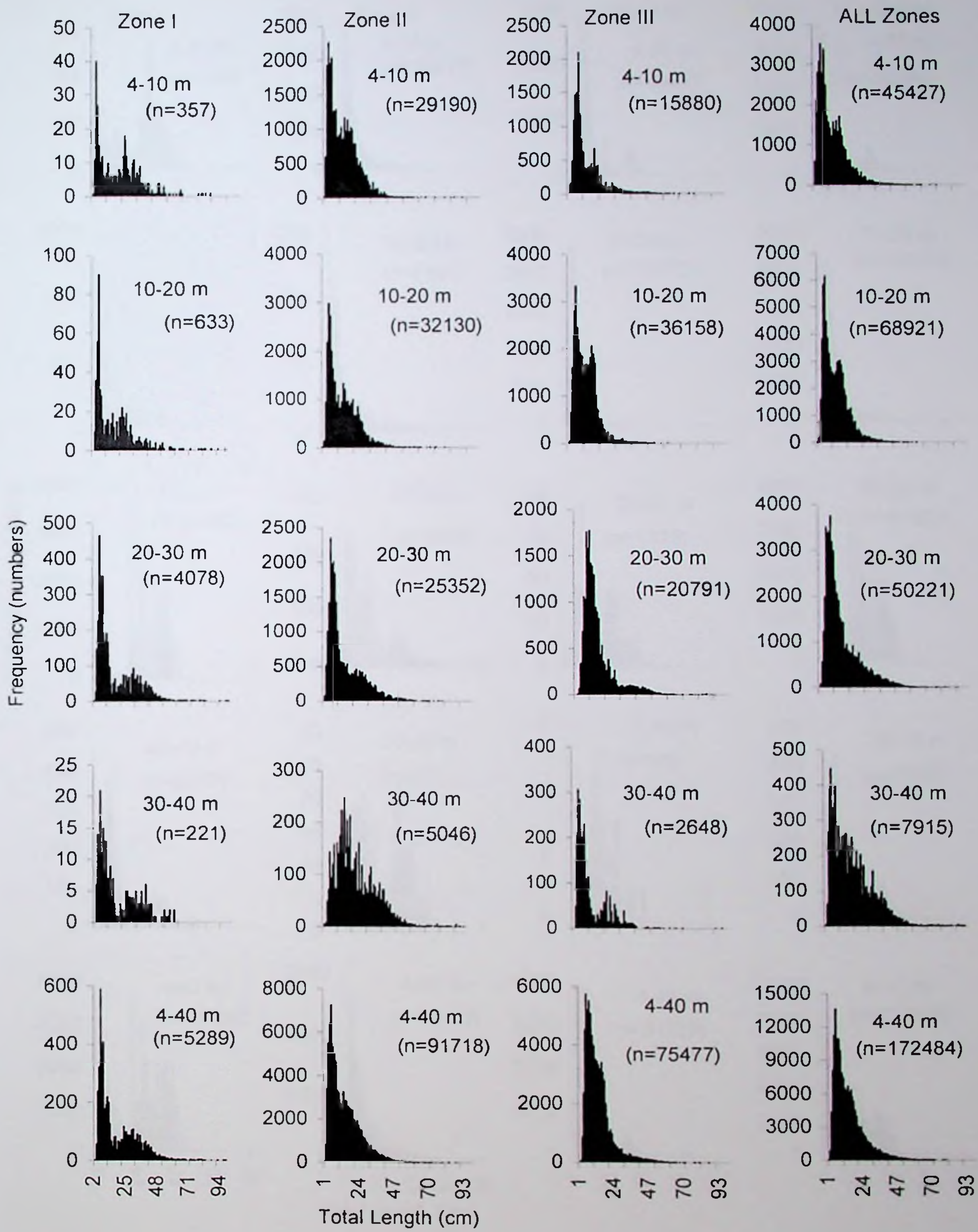


Fig. 7. Length frequency distribution for *Lates niloticus* caught during bottom trawl surveys in the different zones and water depth ranges in the Uganda sector of Lake Victoria during 1999 .
(n = number of fish specimens)

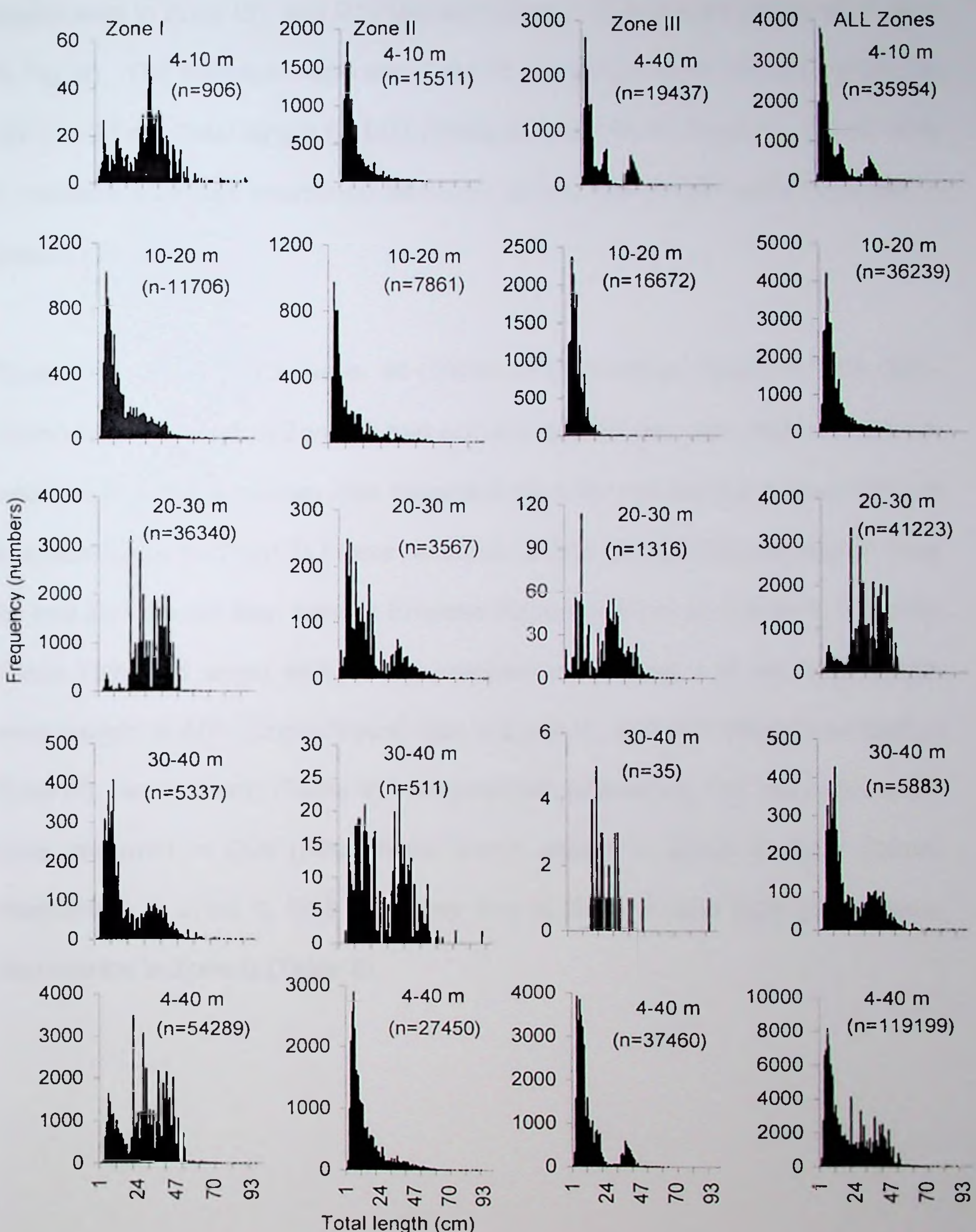


Fig. 8. Length frequency distribution for *Lates niloticus* caught during bottom trawl surveys in the different zones and water depth ranges in the Uganda sector of Lake Victoria during 2000 .
(n = number of fish specimens)

island area in Zone III), and B10 (Berkeley Bay – off Majanji in Zone III) (Table 8, Fig. 9). The average mode was 7 cm TL, ranging from 5 cm total length (in B07) to 28 cm Total length (in D02 (Dimo-Namirembe in Zone I)). About 80% *L. niloticus* juveniles measuring less than 20 cm total length were recorded in waters <20 m deep.

During the 1999-2000 surveys, all (100%) of *O. niloticus* caught in C04 (Mu–Kitobo Island waters in Zone II) had not reached 50 per cent maturity (27 cm total length), the minimum size recommended for harvesting; about 90% of this size range (≥27 cm TL) were recorded in A08 (Lingira/Ekunu Bay in Zone III) and B04 (Bussi Bay, west of Entebbe Airport in Zone II) (Table 9, Fig. 10). About 75% and about 44% of the juveniles measuring <10 cm total length were caught in A08 (Lingira/Ekunu Bay in Zone III) and A07 (Napoleon Gulf in Zone III), respectively, (Table 9). No juveniles measuring <10 cm total length were recorded in C04 ((Mu–Kitobo Island waters in Zone II), D02 (Dimo-Namirembe in Zone I), D03 (Bomangi Bay in Zone II) and E02 (Dimo-Bale-Namirembe in Zone I) (Table 9).

Table 8. Length frequency distribution (percentage by weight) for *Lates niloticus* by grid during the bottom trawl surveys in the Uganda sector of Lake Victoria between . January1999 and December 2000.

	Water Depth						Catch distribution (% by weight)			
				Total Length (cm)			Total length range (cm)			
Grid	Average (m)	Range (m)	Number of fish	Average	Range	Mode	1-20	20-40	40-50	50-183 (mature)
A07	11.8	10-14	9912	12.1	2 - 96	6	86.3	12.9	0.4	0.4
A08	13.3	8-29	19068	11.6	3-105	7	89.4	8.1	1.9	0.6
B04	10.6	3-27	14322	12.7	3 - 95	7	85.1	13.4	0.8	0.7
B05	26.2	22-32	5597	18.1	3-102	8	64.2	28.5	5.2	2.1
B06	27.8	25-31	2374	22.2	2-104	12	59.0	29.3	6.7	5.0
B07	19.9	8-44	49259	15.2	2-104	5	80.7	15.7	2.8	0.8
B08	25.5	15-32	20097	15.2	3-105	12	82.6	12.3	3.3	1.8
B09	18.1	13-26	9398	12.7	3 - 93	7	89.0	7.8	1.8	1.4
B10	14.0	5-25	48862	13.4	3-183	8	84.7	11.7	2.1	1.5
C03	9.0	5-25	60693	14.6	2-135	7	75.8	21.2	1.9	1.1
C04	21.2	9-28	20012	17.8	3-149	7	67.3	25.7	4.5	2.5
C05	26.6	16-55	13259	16.7	2-110	6	66.2	28.6	3.6	1.6
C07	44.2	31-56	1619	17.2	4 - 97	6	56.8	40.1	2.2	0.9
C09	25.5	24-26	2400	17.4	8-113	16	76.4	22.6	0.5	0.5
D02	14.3	9-20	1095	25.6	3-108	28	27.4	63.7	4.1	4.8
D03	12.6	5-23	38568	16.3	2-150	7	68.9	26.3	3.1	1.7
D04	23.6	14-27	11086	13.9	3 - 84	9	76.1	22.1	1.0	0.8
D05	40.8	34-48	353	24.6	4 - 95	16	40.8	51.3	2.5	5.4
E02	15.6	7-23	6704	19.6	4-119	8	63.8	24.1	8.1	4.0
E03	30.5	21-35	12555	23.4	2-129	7	53.9	27.7	11.6	6.8
F02	19.6	15-25	33605	34.6	3 - 86	22	2.4	58.3	36.2	3.1

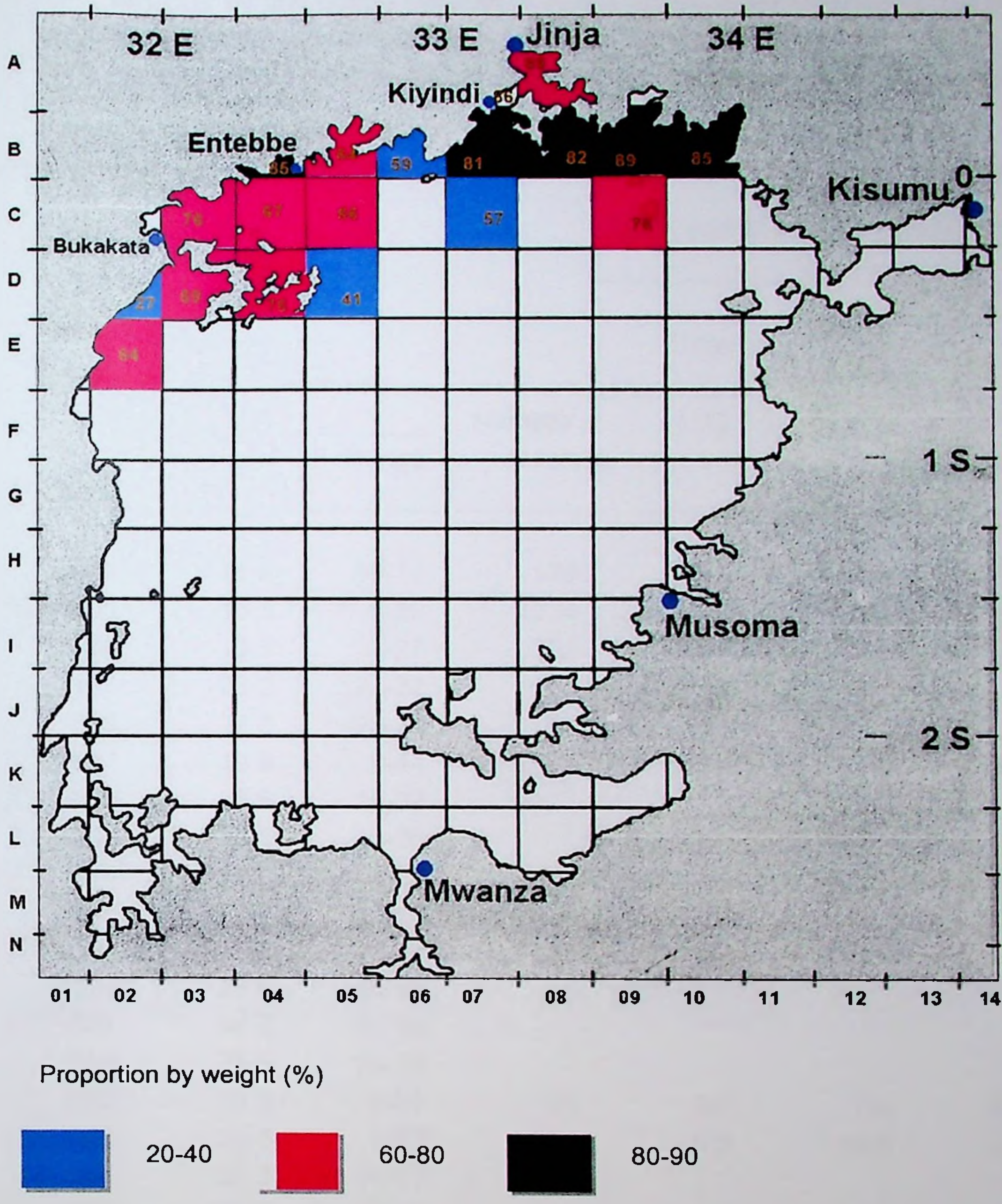


Fig. 9. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing the proportion (percentage by weight) of *Lates niloticus* measuring <20 cm TL during bottom trawl surveys in the Uganda sector between January 1999 and December 2000.

[See Table 1 for summary information on the grids surveyed]

Table 9. Length frequency distribution (percentage by weight) for *Oreochromis niloticus* by grid during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
(Blank entries indicate NIL catches or trace catches of <0.05% by weight)

	Water Depth (m)			Catch distribution (% by weight)		
				Total length range (cm)		
Grid	Average	Range	Number of fish	1-10	10-27	27-67 (Mature)
A07	11.8	10-14	148	43.9	30.4	25.7
A08	13.3	8-29	1234	74.4	15.6	10.1
B04	10.6	3-27	502	17.5	73.3	9.2
B05	26.2	22-32				
B06	27.8	25-31				
B07	19.9	8-44	2133	29.4	39.8	30.8
B08	25.5	15-32				
B09	18.1	13-26				
B10	14.0	5-25				
C03	9.0	5-15	1426	0.7	3.0	96.3
C04	21.2	9-28	35	0.0	100.0	0.0
C05	26.6	16-55				
C07	44.2	31-56				
C09	25.5	24-26				
D02	14.3	9-20	64	0.0	1.6	98.4
D03	12.6	5-23	307	0.0	19.5	80.5
D04	23.5	14-27				
D05	40.8	34-48				
E02	15.6	7-23	49	0.0	2.0	98.0
E03	30.5	21-35				
F02	19.6	15-25				

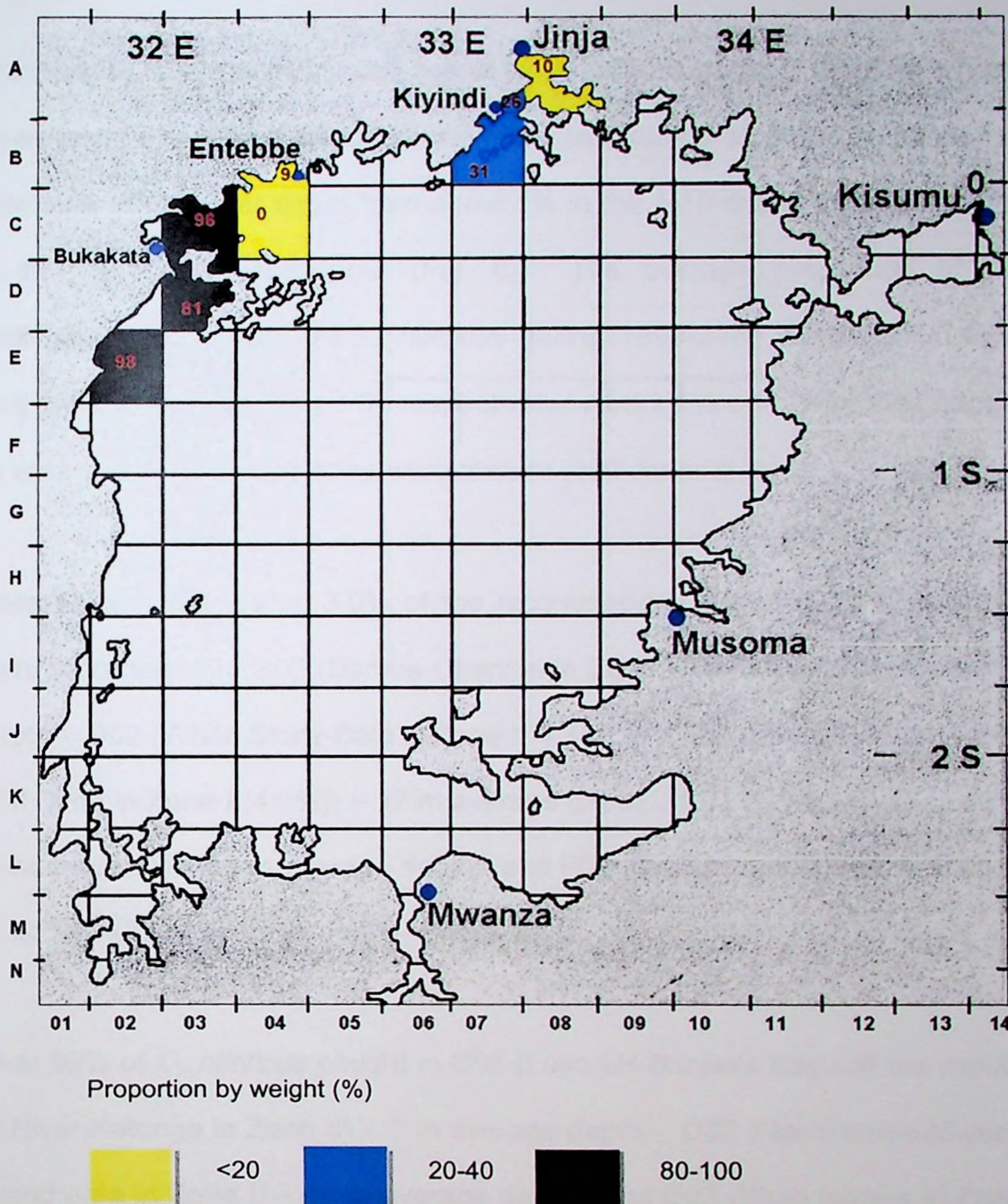


Fig. 10. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing the proportion (percentage by weight) of mature (27 cm TL) *Oreochromis niloticus* during bottom trawl surveys in the Uganda sector between January 1999 and December 2000.

4.1.1.2. ***Distribution of the adult fish***

Numerically, the recommended harvestable *L. niloticus* (≥50 cm total length) averaged 1.8% in the Uganda sector of the lake during 1999/2000, increasing with increasing water depth from about 1% in the 4-10 m depth area to 3.7% in the 30-40 m depth area (Fig. 6). The average proportion of the recommended harvestable *L. niloticus* during 1999/2000 were 3.7%, 1.6% and 1.0% in Zones I, II and III, respectively. About 1% of the catches caught in waters less than 20 m deep were mature (≥50 cm total length).

Catches with more than 3.0% of the recommended harvestable *L. niloticus* were recorded from B06 (Damba Channel in Zone II (5.0%)) – 29 m average depth -, D02 (White Stony-Bale in Zone I (4.8%)) – 17 m average depth -, E02 (Off Dimo in Zone I (4.0%)) – 17 m average depth -, E03 (Lujabwa-Linga Pt in Zone I (6.8%)) – 30 m average depth - and F02 (Masambwa-Lujabwa in Zone I (3.1%)) – 25 m average depth - (Table 8).

Over 96% of *O. niloticus* caught in C03 (Luyo LH-Bunjako Bay, off the mouth of River Katonga in Zone II) – 7 m average depth -, D02 (Namirembe-Mweza Island area in Zone I) – 10 m average depth - and E02 (Dimo waters in Zone I) – 12 m average depth - were mature (Table 9, Fig. 10).

4.1.1.3. *Distribution of sexes*

The sex ratios of female (F) to male (M) *L. niloticus* averaged 1:5 and 1:3 during 1999 and 2000, respectively (Table 10). It varied with the habitat (grid), ranging from 1:3 in B10 (Berkeley Bay – off Majanji in Zone III) to 1:10 in B09 (Luvangu-Simu Island area in Zone III) and 1:17 in E03 (Linga-Lujabwa Island area – south of Bugala Island, Kalangala District in Zone I) during 1999 and from 1:2 in A08 (Lingira/Ekunu Bay in Zone III), B07 (Itome Bay in Zone III), B08 (Mvuja Island area – west of Luvia and Dagusi Islands in Zone III) and B09 (Luvangu-Simu Island area in Zone III) to 1:6 in B04 (Bussi and Entebbe Bays in Zone II) during 2000. The observed sex ratios for L. niloticus were statistically different from ~~form~~ the theoretical (1F:1M) during the surveys in 1999 ($X^2{}_{,1}=2.7$, $p<0.05$) and in 2000 ($X^2{}_{,1}=1.0$, $p<0.05$)

4.1.2. Fish species composition and distribution in gill net surveys

In the inshore shallow waters, the gill net catches comprised a total of 11 fish taxa (belonging to 9 genera): *Astatoreochromis* sp, *Brycinus jacksonni, Clarias gariepinus, Haplochromis* spp., *Labeo victorianus, Lates niloticus, Oreochromis leucostictus, O. niloticus, O. variabilis, Synodontis afrofischeri* and *Tilapia zillii* (Appendix 7).

Oreochromis niloticus dominated the catches, contributing 44.59% by weight, in all the areas surveyed, followed by *L. niloticus* (19.18%), *Haplochromis* spp.

Table 10. Sex ratios of *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000. [FEM. = Female, Imm. = immature]

	1999					2000				
	Number			Ratio		Number			Ratio	
Grid	Male	Fem.	Imm.	Male	Fem.	Male	Fem.	Imm.	Male	Fem.
A07										
A08						33	14	13	2	1
B04	102	23	15	4	1	28	5	8	6	1
B05	94	18	21	5	1	20	7	1	3	1
B06										
B07	78	15	21	5	1	76	43	62	2	1
B08	0	0	24			30	8	22	4	1
B09	58	6	23	10	1	21	12	12	2	1
B10	134	42	34	3	1	126	54	15	2	1
C03	304	58	31	5	1	180	67	75	3	1
C04	157	21	11	7	1	146	33	23	4	1
C05	136	30	19	5	1	8	7	5	1	1
C06	143	30	29	5	1					
C07	47	10	5	5	1					
C09	8	2	1	4	1					
D03						147	51	35	3	1
D04										
D05										
E02	51	8	0	6	1	106	32	22	3	1
E03	52	3	7	17	1	81	20	19	4	1
F02						48	17	15	3	1
Total	1364	266	241	5	1	1050	370	327	3	1

Table 11. Composition of fish catch (percentage by weight) by species during multi-mesh monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001 (MacDonald Bay, Fielding Bay, Napoleon Gulf and Entebbe area)

Fish species	Catch composition (percentage by weight)											
	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April/ May 2001	June/ July 2001	July 2001	July/ Aug 2001	Sep 2001	2000 -2001
Astatoreochromis sp.	0.37	0.00	0.00		0.00	0.00	3.92	0.08	0.00	0.00	0.48	0.54
Brycinus jacksonni	1.66	0.79	4.27	1.12	4.20	1.12	8.41	2.55	0.00	4.98	0.00	3.58
Clarias gariepinus	2.47	0.00	0.00		12.75	0.00	0.00	0.00	0.00	0.00	0.00	2.31
Haplochromis spp.	10.17	9.26	11.23	6.45	29.59	17.64	17.88	22.38	46.90	24.32	28.61	18.32
Labeo victorianus	0.00	0.58	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Lates niloticus	34.98	22.71	13.24	16.50	9.86	52.81	9.17	15.88	9.82	7.29	65.02	19.18
Oreochromis leucostictus	0.00	0.00	2.56	1.89	1.54	1.78	3.77	4.70	0.00	1.60	0.00	2.16
O. niloticus	45.86	58.38	60.34	62.29	33.35	12.04	45.35	46.60	11.77	51.90	3.20	44.59
O. variabilis	0.00	0.00	0.25		0.00	0.00	0.40	0.91	0.00	0.00	1.64	0.24
Synodontis afrofischerie	0.00	0.00	0.00		0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Tilapia zillii	4.48	8.28	8.10	11.76	8.72	14.61	11.11	6.83	31.51	9.91	1.05	9.04
Total weight (kg)	46.5	26.0	79.1	32.8	79.2	41.3	59.7	62.8	3.0	47.0	10.3	487.8

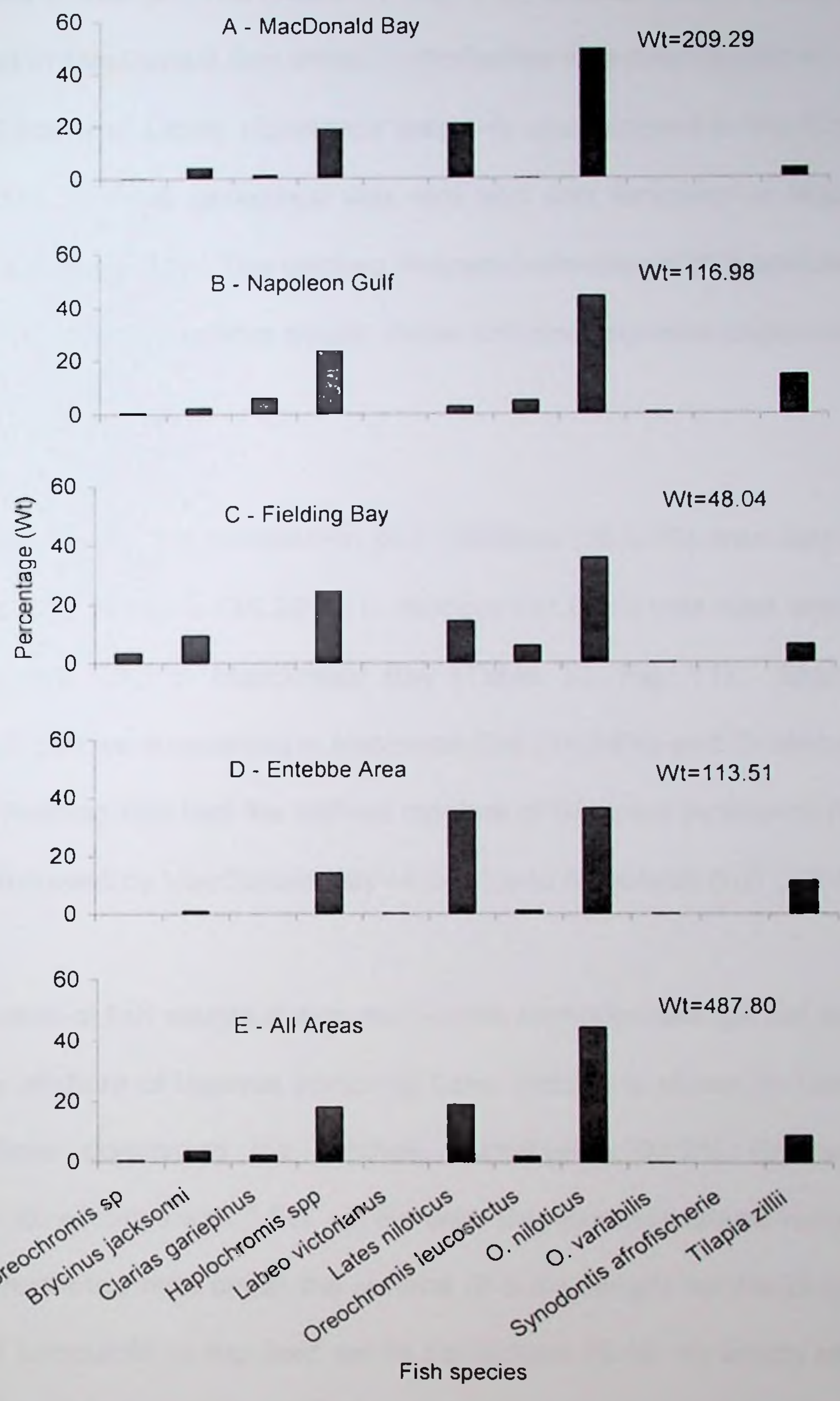


Fig. 11 . Composition (percentage by weight) of fish caught during multi-mesh monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001.

(18.32%) and *T. zillii* (9.04%) (Table 11, Fig. 11). *Oreochromis variabilis* was not recorded in MacDonald Bay while *S. afrofischeri* was only caught in MacDonald Bay and *Labeo victorianus* was only encountered in the Entebbe area (Fig. 11). *Clarias gariepinus* was rare and was recorded in Napoleon Gulf and MacDonald Bay. The catches indicated retention of fish species that were rarely recorded in bottom trawls; these included *Brycinus jacksonni* and *O. leucostictus*.

In the Entebbe area, the contribution of *L. niloticus* (35.37%) was very close and second to *O. niloticus* (36.39%); *L. niloticus* (21.04%) was also second to *O. niloticus* (49.72%) in MacDonald Bay (Table 12, Fig. 11). Significant catches of *T. zillii* were recorded in Napoleon Gulf (14.54%) and Entebbe area (11.55%). Fielding Bay had the highest catches of *Brycinus jacksonni* (9.51% by weight) followed by MacDonald Bay (4.24%) and Napoleon Gulf (2.24%).

The distribution of fish caught during multi-mesh monofilament gill net surveys in the deep offshore of Uganda portion of Lake Victoria is shown in Table 13. *Lates niloticus* dominated the catches, contributing 93.2% (by weight), followed by *O. niloticus* with 3.5%. In Bunjako Bay-Buninga island waters (10 m maximum depth), nets set at the surface (0-5 m) caught 99.3% of the fish (by weight) compared to the fleet set at the bottom (5-10 m) which retained less than 1% of the catch. Similar observations were made in Buvuma channel-Lingira Island (17 m maximum depth) where all the catch was obtained from the nets set at 0-11 m while the nets set at the bottom (12-17 m) did not retain any fish.

In the deeper waters of – maximum depth is shown in brackets – Damba Channel-Mbazi Hills (24 m) in Zone II, Nsadzi-Jana Islands (44 m) in Zone II and Mu Island (23 m) in Zone II, 81.6% of the fish (by weight) were retained by the nets set at the bottom; the nets set at the surface (0-5 m) retained 6.4% of the fish while some of the nets set in mid-water did not retain any fish (Table 13).

The survey results from Busiji Pt-Mvuja Island and Sigulu Island – both 26 m maximum depth and in Zone III – differed. In Busiji Pt-Mvuja Island, 83% of the fish (by weight) was retained by nets set at the surface (0-5 m) while in Sigulu Island 55.6% and 40.8% of the fish were retained by the nets set at surface (0-5 m) and the bottom (21-26 m), respectively. The nets set at the bottom (21-26 m) in Busiji Pt-Mvuja Island did not retain any fish.(Table 13).

4.1.2.1. ***Distribution of the small fish***

Table 14 shows the numerical length frequency distribution for *L. niloticus* caught in monofilament gill net surveys during the period April 2000 to September 2001. During the survey period (April 2000 to September 2001), about 98% of the fish measured 10-30 cm total length. The juvenile fish measuring less than 20 cm total length contributed 72.3, 82.9, 78.4 and 82.7% of the fish caught in Fielding Bay, MacDonald Bay, Napoleon Gulf and Entebbe area, respectively. No fish measuring less than 10 cm total length

Table 12. Composition of fish catch (percentage by weight) by location during multi-mesh monofilament gill net surveys in in the Uganda sector of Lake Victoria between April 2000 and September 2001.

		Percentage Composition (by weight)											
Location	Fish species	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April May 2001	June July 2001	July 2001	July Aug 2001	Sep 2001	2000 -2001
MacDonald Bay (Bugoto area)	*Oreochromis niloticus*	50.52		57.68		36.83		34.64	47.22		65.04		49.72
	Lates niloticus	27.21		21.45		18.72		25.24	21.16		10.75		21.04
	Other species	22.27		20.87		44.45		40.12	31.62		24.21		29.24
Napoleon Gulf	*Oreochromis niloticus*			63.81		28.92		51.31	49.65		47.08		44.13
	Lates niloticus			2.51		3.31		1.22	3.31		1.71		2.85
	Other species			33.68		67.77		47.47	47.04		51.21		53.02
Fielding Bay	*Oreochromis niloticus*			54.15		47.82		47.39	15.55		19.74		35.74
	Lates niloticus	100.00		8.73		2.84		3.74	14.03		3.42		14.30
	Other species	0.00		37.12		49.34		48.87	70.42		76.84		49.96
Entebbe area	*Oreochromis niloticus*		58.38		62.29		12.04			11.77		3.20	36.39
	Lates niloticus		22.71		16.50		52.81			9.82		65.02	35.37
	Other species		18.91		21.21		35.15			78.41		31.78	28.24

Table 13. Distribution of fish caught during multi-mesh monofilament gill net surveys in the offshore waters of the Uganda sector of Lake Victoria during November/December 1999.

Date	Location	Max. Water Depth (m)	Water Depth set (m)	Fish species	No.	Average Total Length (cm)	Total Weight (kg)	% Total weight
3. 11 1999	Damba Channel-Mbazi Hill	24	0-5	*Haplochromis* spp	1	10.0	0.01	0.17
				O. niloticus	1	28.0	0.45	7.67
				L. niloticus	61	18.0	5.41	92.16
			6-11		EMPTY			
4.11.1999	Nsadzi Island-Jana Island	44	0-5	*L. niloticus*	1	18.0	0.05	0.62
			13-18		EMPTY			0.00
			26-31	*L. niloticus*	7	23.3	1.26	15.73
			39-44	*L. niloticus*	29	25.1	6.70	83.65
5.11.1999	Mu Island	23	0-5	*L. niloticus*	1	31.0	0.20	5.67
			6-11	*L. niloticus*	6	24.3	0.85	24.06
			12-17	*L. niloticus*	3	20.0	0.20	5.78
			18-23	*L. niloticus*	26	19.0	2.28	64.48
10.11.1999	Bunjako Bay-Buninga Island	10	0-5	*L. niloticus*	15	22.5	2.02	99.26
			5-10	*Haplochromis* spp	2	11.1	0.02	0.74
11.12.1999	Busiji Pt-Mvuja Island	26	0-5	*Haplochromis* spp	1	9.0	0.05	0.61
				L. niloticus	47	20.8	6.83	83.18
			7-12		EMPTY			0.00
			14-19		21	17.2	1.33	16.21
			21-26		EMPTY			
12.12.1999	Sigulu Island	26	0-5	*L. niloticus*	8	26.4	1.71	55.63
			7-12	*L. niloticus*	1	22.0	0.05	1.63
			14-19	*Haplochromis* spp	1	9.2	0.01	0.33
				L. niloticus	1	21.0	0.05	1.63
			21-26	*L. niloticus*	7	25.9	1.25	40.78
16.12.1999	Buvuma Channel-Lingira Island	17	0-5	*Haplochromis* spp	1	11.1	0.01	0.69
				L. niloticus	6	17.0	0.31	15.23
				O. niloticus	1	35.0	0.75	37.09
			6-11	*Synodontis afrofisch*	1	13.0	0.03	1.48
				L. niloticus	2	31.0	0.92	45.50
			12-17		EMPTY			

were retained in Napoleon Gulf and Fielding Bay during the survey period while 2 fish specimens measuring 9.5 cm and 1 fish specimen of 7 cm total length were caught in MacDonald Bay in April 2000 and February 2001, respectively, and 1 fish measuring 9.5 cm total length was recorded in Entebbe area in April 2001. However, 59.8, 52.7, 51.4 and 62.3 % (by weight) of *L. niloticus* caught in Fielding Bay, MacDonald Bay, Napoleon Gulf and Entebbe area, respectively, measured less than 20 cm total length (Table 15).

The bulk (about 98% by numbers) of *O. niloticus* caught in monofilament gill net surveys during the period April 2000 to September 2001 had not reached 27 cm total length, the size at first maturity for the species (Table 16). The juvenile fish measuring less than 15 cm total length contributed 39.9, 42.4, 48.1 and 22.2% of the catch (by numbers) in Fielding Bay, MacDonald Bay, Napoleon Gulf and Entebbe area, respectively. Fish of less than 5 cm total length were not caught during the survey in both the open deep water and the shallow (<4 m) inshore water areas.

4.1.2.2. ***Distribution of adult fish***

The biggest *L. niloticus* caught during monofilament gill net survey measured 38.0 cm total length, a size less than 50 cm total length at which the species attains first maturity. The only two specimens (measuring 38.0 cm total length) were caught in MacDonald Bay during April 2000 and in Napoleon Gulf during February 2001.

Table 14. Population structure of *Lates niloticus* caught (numbers) in monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001.

Location	TL (cm)	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April/ May 2001	June/ July 2001	July 2001	July/ Aug 2001	Sep 2001	2000/ 2001 (%)
Fielding	1-10												
Bay	10-20	42		9		4		8	13		5		72.3
	20-30	19				1		3	6				25.9
	30-40	1									1		1.8
	=40												
	Total	62		9		5		11	19		6		
MacDonald	1-10	2				1							0.4
Bay	10-20	129		91		85		97	130		42		82.8
	20-30	25		13		23		10	12		18		14.6
	30-40	5		4		1		1	3		1		2.2
	=40												
	Total	161		108		110		108	145		61		
Napoleon	1-10												
Gulf	10-20			12		13		3	1				78.4
	20-30					4		1	2				18.9
	30-40					1							2.7
	=40												
	Total			12		18		4	3				
Entebbe	1-10						1						0.2
Area	10-20		56		82		240			8		130	82.7
	20-30		12		11		50					30	16.5
	30-40		3		1								0.6
	=40												
	Total		71		94		291			8		160	

Table 15. Population structure of *Lates niloticus* caught (kg) in monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001.

Location	TL (cm)	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April/ May 2001	June/ July 2001	July 2001	July/ Aug 2001	Sep 2001	2000 -2001 (%)
	10-20	2.8		7.4		2.6		0.6	1.0		0.3		59.8
	20-30	2.5				0.1		0.2	0.5				34.4
	30-40	2.3									0.3		5.8
	40-50												
	50-60												
	>60												
	Total	7.7		7.4		2.7		0.9	1.5		0.6		
MacDonald Bay	1-10	0.0				0.0							0.1
	10-20	4.8		3.9		3.3		3.6	6.9		1.8		52.5
	20-30	3.9		1.6		4.0		1.5	1.8		3.5		35.3
	30-40	2.3		1.4		0.3		0.3	1.1		0.2		12.2
	40-50												
	50-60												
	>60												
	Total	11.1		6.8		7.7		5.5	9.8		5.5		
Napoleon Gulf	1-10												
	10-20			0.6		0.6		0.2	0.1				51.4
	20-30					0.5		0.1	0.1				26.5
	30-40					0.6							22.1
	40-50												
	50-60												
	>60												
	Total			0.6		1.7		0.3	0.2				
Entebbe Area	1-10						0.0						0.0
	10-20		2.8		3.1		10.1			0.2		5.1	62.3
	20-30		1.0		1.7		5.7					3.6	34.9
	30-40		0.9		0.1								2.8
	40-50												
	50-60												
	>60												
	Total		4.7		4.9	0.0	15.9			0.2		8.7	

Mature *O. niloticus* (measuring at least 27 cm total length – size at 50% maturity) contributed 3.6, 2.5, 1.3 and 3.7% of the catch (by numbers) in Fielding Bay, MacDonald Bay, Napoleon Gulf and Entebbe area, respectively (Table 16). The corresponding contributions of the mature fish in the catch (by weight) in Fielding Bay, MacDonald Bay, Napoleon Gulf and Entebbe area were 11.3, 10.5, 6.8 and 16.3%, respectively (Table 17). The mature fish were caught during September 2000, April/May 2001 and July 2001 in Fielding Bay, during February 2001, April 2000, February 2001, April/May 2001, June/July 2001 and July/August 2001 in McDonald Bay, during April/May 2001, June/July 2001 and July/August 2001 in Napoleon Gulf, and during May 2000, October 2000 and April 2001 in Entebbe area (Tables 16 & 17).

Table 16 Population structure of *Oreochromis niloticus* caught (numbers) in monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001. (* 27 cm TL = size at 50% maturity).

Location	TL (cm)	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April/ May 2001	June/ July 2001	July 2001	July/ Aug 2001	Sep 2001	2000 -2001 (%)
Fielding	5-10								1		6		5.1
Bay	10-15			5		10		2	3		28		34.8
	15-20			12		16		2	4				24.6
	20-25			9		8		9	4		7		26.8
	25-30			1		1		6	1				6.5
	30-35			2				1					2.2
	* =27			2				2	1				3.6
MacDonald	5-10	29		2		1		15	11		14		8.1
Bay	10-15	118		7		30		48	53		50		34.3
	15-20	73		72		30		20	56		68		35.8
	20-25	13		57		18		9	24		25		16.4
	25-30	10		4		17		2	5		3		4.6
	30-35	2							2		1		0.6
	35-40								1				0.1
	40-45										1		0.1
	* =27	7				5		1	5		4		2.5
Napoleon	5-10			10		1			7		1		3.5
Gulf	10-15			158		24		6	16		35		44.6
	15-20			73		47		18	15		2		28.9
	20-25			9		18		49	19		3		18.3
	25-30			1		5		6	6		4		4.1
	30-35								1		2		0.6
	* =27					1		1	3		2		1.3
Entebbe	5-10											1	0.4
Area	10-15		34		17		4					4	21.8
	15-20		66		40		6			1		1	42.1
	20-25		23		32		14			1			25.8
	25-30		5		14		2						7.7
	30-35		2		2								1.5
	35-40				1								0.4
	40-45				1								0.4
	* =27		4		5		1						3.7

Table 17. Population structure of *Oreochromis niloticus* caught (kg) in monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001. (* 27 cm TL = size at 50% maturity).

Location	TL (cm)	April 2000	May 2000	Sep 2000	Oct 2000	Feb 2001	April 2001	April/ May 2001	June/ July 2001	July 2001	July/ Aug 2001	Sep 2001	2000 -2001 (%)
Fielding	5-10								0.0		0.1		0.6
Bay	10-15			0.2		0.4		0.1	0.1		0.7		8.5
	15-20			1.3		1.4		0.2	0.4				19.1
	20-25			1.9		1.7		2.4	0.9		1.1		46.0
	25-30			0.3		0.5		2.1	0.4				19.0
	30-35			0.4				0.8					6.9
	* =27			0.4				1.2	0.4				11.3
MacDonald	5-10	0		0.0		0.0		0.2	0.3		0.2		1.1
Bay	10-15	6		0.5		0.9		1.6	2.8		2.2		13.1
	15-20	8		11.8		2.4		2.1	6.6		6.5		35.6
	20-25	3		13.6		3.5		1.7	6.0		5.2		31.6
	25-30	3		1.6		5.8		0.8	1.6		1.3		13.7
	30-35	1							0.8		0.5		2.7
	35-40								0.3				0.3
	40-45										1.9		1.8
	* =27	3				2.0		0.5	1.8		3.3		10.5
Napoleon	5-10			0.2		0.0			0.1		0.0		0.5
Gulf	10-15			8.3		0.9		0.1	0.6		1.3		20.5
	15-20			6.5		4.1		2.1	1.5		0.1		26.0
	20-25			1.1		3.2		10.6	3.7		0.7		35.0
	25-30			0.2		1.8		2.2	2.3		1.4		14.5
	30-35								0.7		1.3		3.5
	* =27					0.4		0.4	1.6		1.3		6.8
Entebbe	5-10											0.0	0.0
Area	10-15		1.6		0.7		0.2					0.1	6.1
	15-20		6.8		3.8					0.1		0.2	27.4
	20-25		4.8		7.3		3.3			0.2			36.8
	25-30		1.8		4.7		0.9						17.4
	30-35		1.2		1.5								6.4
	35-40				1.2								2.8
	40-45				1.3								3.0
	* =27		2.0		4.3		0.5						16.3

4.1.2.3. ***Distribution of the sexes***

The sex ratios of female to male *L. niloticus* from monofilament gill nets during the survey period under report averaged 1 female to 9, 6 and 6 male fish in MacDonald Bay, Fielding Bay and Entebbe area, respectively; the ratios ranged from 1 female fish to from 7 to 19, 3 to 7 and 6 to 11 male fish in the same areas, respectively (Table 18). In Napoleon Gulf, the numbers were scanty although a 1:1 was indicated.

The ratios of female to male *O. niloticus* fluctuated around 1:4, averaging 1 female fish to 5, 3, 2 and 3 male fish in MacDonald Bay, Fielding Bay, Entebbe area and Napoleon Gulf, respectively; the ratios ranged from 1 female to from 3 to 6, 1 to 11, 2 to 3, and 1 to 5 male fish in the same areas (Table 19).

The chi-square test showed that the observed sex ratios for *L. niloticus* were statistically different from the theoretical (1F:1M) ($X^2{}_{,1}$=4.5, $p < 0.05$) while the observed ratios for *O. niloticus* were statistically not different from the theoretical ($X^2{}_{,1}$=1.8, $p > 0.05$)

Table 18. Sex ratio (F:M) and number of spawning *Lates niloticus* caught during monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001. (F = female fish, M = male fish, All = all fish including the immature, Spa = spawning).

		April 2000		May 2000		Sep 2000		Oct 2000		Feb 2001		April 2001		April/May 2001		June/July 2001		July 2001		July/Aug 2001		Sep 2001		2000 2001
Location	Sex	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All	Spa	All
MacDonald	All	162				108				111				109		145				61				696
Bay	M	100	1			79	0			87	0			77	0	85	0			38	0			466
	F	15	0			6	0			13	0			4	0	13	0			3	0			54
	F:M	1:7				1:13				1:7				1:19		1:7				1:13				1:9
Fielding Bay	All	62				9				4				11		19				6				111
	M	41	0			2	0									4	0			3	0			50
	F	6	0													1	0			1	0			8
	F:M	1:7														1:4				1:3				1:6
Entebbe Area	All			71				94				291						8				161		625
	M			21	0			68	0			162	0					1	0			48	0	300
	F			2	0			12	0			29	0									8	0	51
	F:M			1:11				1:6				1:6										1:6		1:6
Napoleon Gulf	All					12				18				4		3								37
	M									4	0													4
	F									2	0			1	0									3
	F:M									1:2														1:1

Table 19. Sex ratio (F:M) and number of spawning *Oreochromis niloticus* caught during monofilament gill net surveys in the Uganda sector of Lake Victoria between April 2000 and September 2001. (F = female fish, M = male fish, All = all fish including the immature, Spa = spawning)

Location	Sex	April 2000 All	April 2000 Spa	May 2000 All	May 2000 Spa	Sep 2000 All	Sep 2000 Spa	Oct 2000 All	Oct 2000 Spa	Feb 2001 All	Feb 2001 Spa	April 2001 All	April 2001 Spa	April/May 2001 All	April/May 2001 Spa	June/July 2001 All	June/July 2001 Spa	July 2001 All	July 2001 Spa	July/Aug 2001 All	July/Aug 2001 Spa	Sep 2001 All	Sep 2001 Spa	2000 2001 All
MacDonald	All	245				142								94		152				162				795
Bay	M	140	0			13	0							50	0	58	1			129	2			390
	F	27	1			4	0							15	2	11	4			21	3			78
	F:M	1:5				1:3								1:3		1:5				1:6				1:5
Fielding Bay	All					29				35				20		13				41				138
	M					22	0			16	0			12	4	11	1			36	0			97
	F					2	0			17	3			8	2	1	0			5	2			33
	F:M					1:11				1:!				1:2		1:11				1:7				1:3
Entebbe Area	All			130				107				26						2				6		271
	M			76	1			52	0			20	0					2	0			2	0	152
	F			35	1			20	2			6	0									1	0	62
	F:M			1:2				1:3				1:2										1:2		1:2
Napoleon Gulf	All					251				95				79		64				47				536
	M					10	0			20	1			4	0	50	2			43	1			127
	F					2	0			21	4			2	0	13	3			3	1			41
	F:M					1:5				1:1				1:2		1:4				1:14				1:3

4.2. Fish stock abundance

The estimated indices of abundance of fish stocks in bottom trawl surveys in in the Uganda portion of Lake Victoria during January 1999 to December 2000 in the different zones, water depth and seasons are shown in Figures 12, 13,14 & 15.

4.2.1. Fish stock abundance by water depth

In Zone I, peak catches of 12.39±2.7 and 12.12±2.4 tonnes km^{-2} were estimated for all species and *L. niloticus*, respectively, in the 20-30 m depth area during 1999 (Fig. 14) (details in Appendix 8). Similarly, the highest catches of 30.80±6.2 and 30.28±6.3 tonnes km^{-2} were estimated for all species and *L. niloticus*, respectively, in the 20-30 m depth waters of Zone I during 2000. The estimated abundance of fish in Zone II increased with increasing water depth during 1999 from 12.50±1.9 and 10.01±1.7 tonnes km^{-2} for all species and *L. niloticus*, respectively, in waters 4-10 m deep to 15.66±3.0 and 15.35±2.9 tonnes km^{-2} for all species and *L. niloticus*, respectively, in waters 30-40 m deep (Fig. 14). During 2000, however, the estimated abundance of all fish species in Zone II decreased with increasing water depth from 11.37±2.2 tonnes km^{-2} in 4-10 m to 6.97±3.7 tonnes km^{-2} in 30-40 m; the abundance of *L. niloticus* in Zone II, on the contrary, initially increased from 5.70±0.9 tonnes km^{-2} in 4-10 m to 8.72±1.4 tonnes km^{-2} in 10-20 m then dropped to 6.81±2.2 and 6.83±3.7 tonnes km^{-2} in 20-30 m and 30-40 m, respectively.

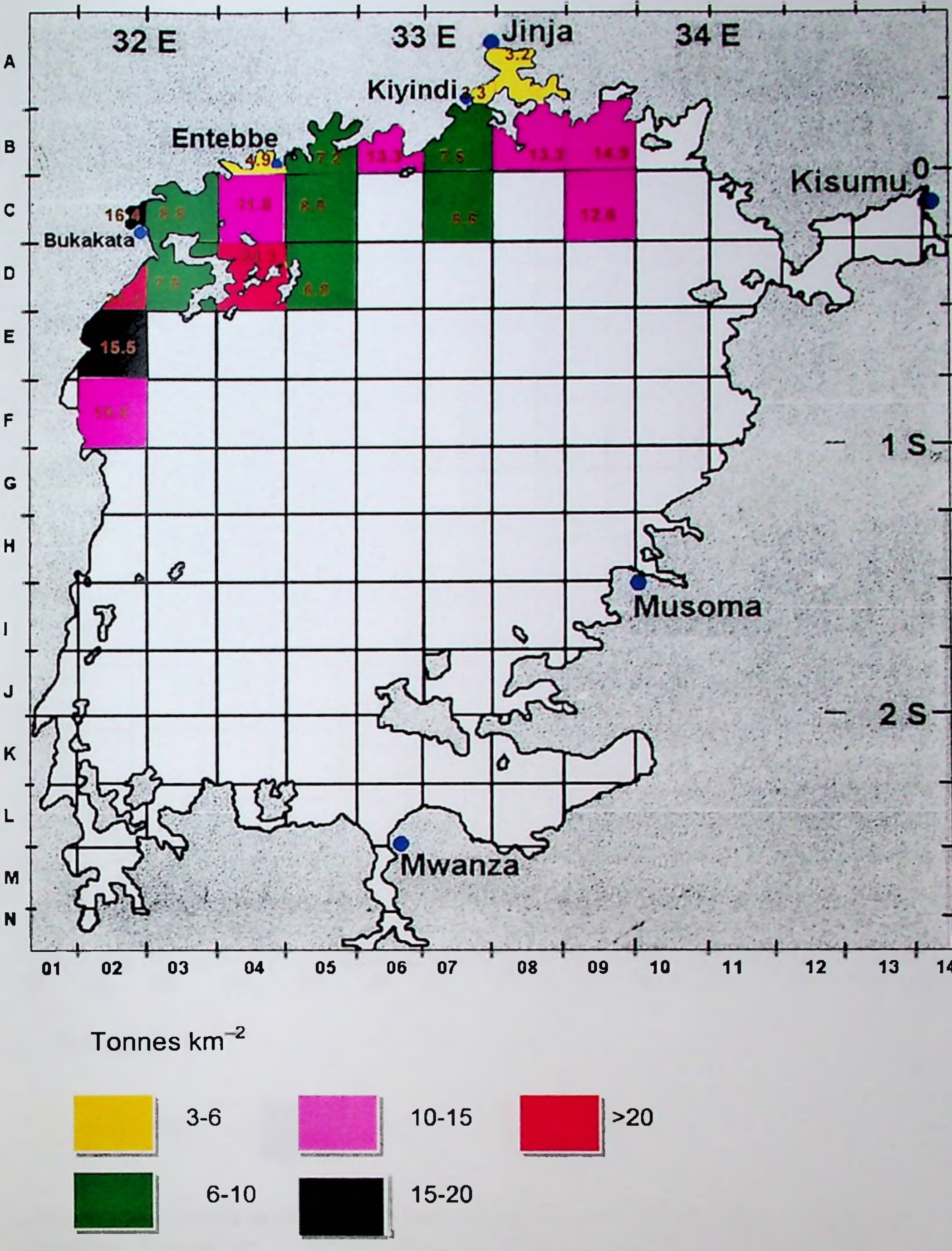


Fig. 12. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Lates niloticus* caught during bottom trawl surveys in the Uganda sector between January 1999 and December 2000.

[See Table 1 for summary information on the grids surveyed]

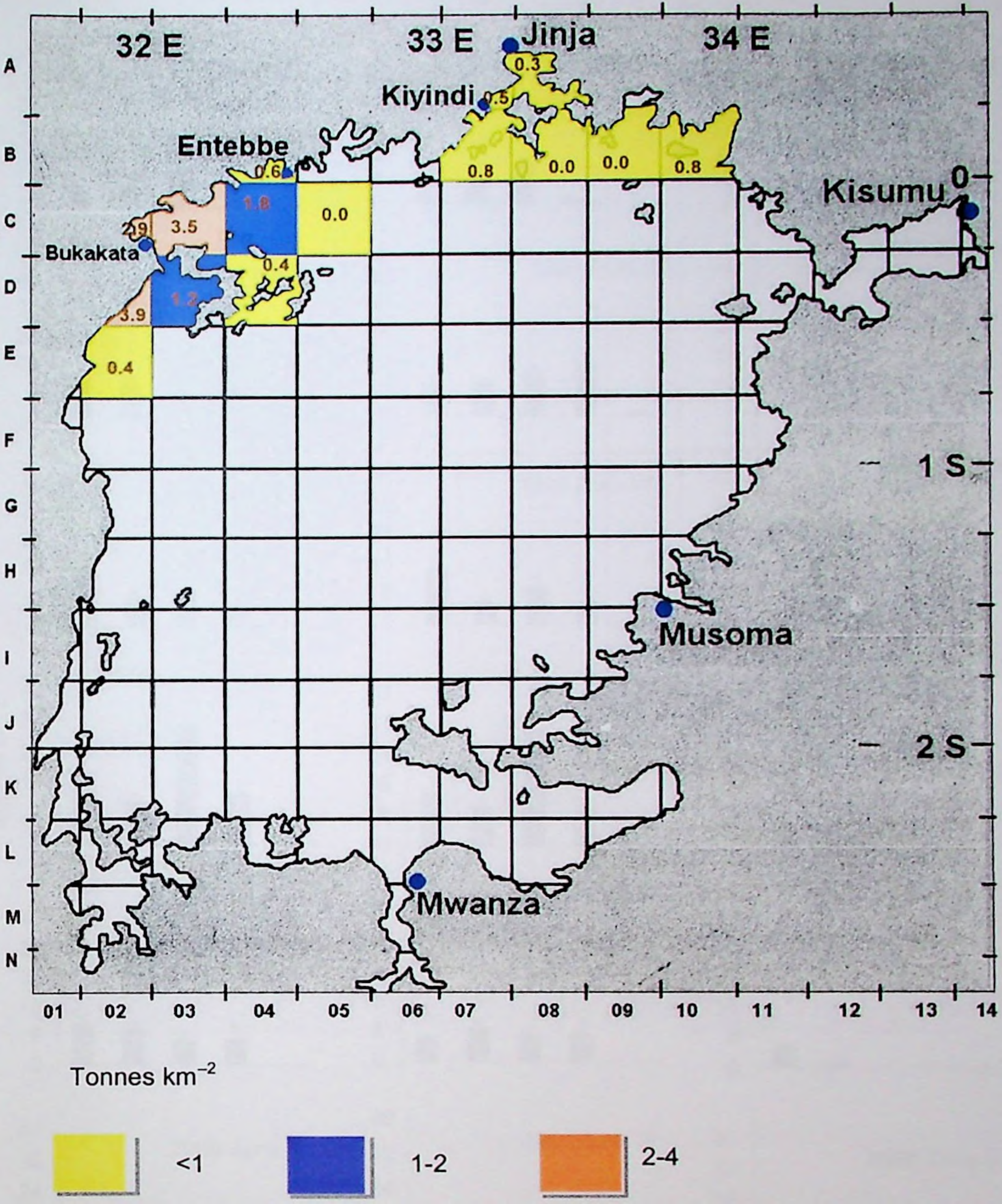


Fig. 13. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda sector between January 1999 and December 2000.

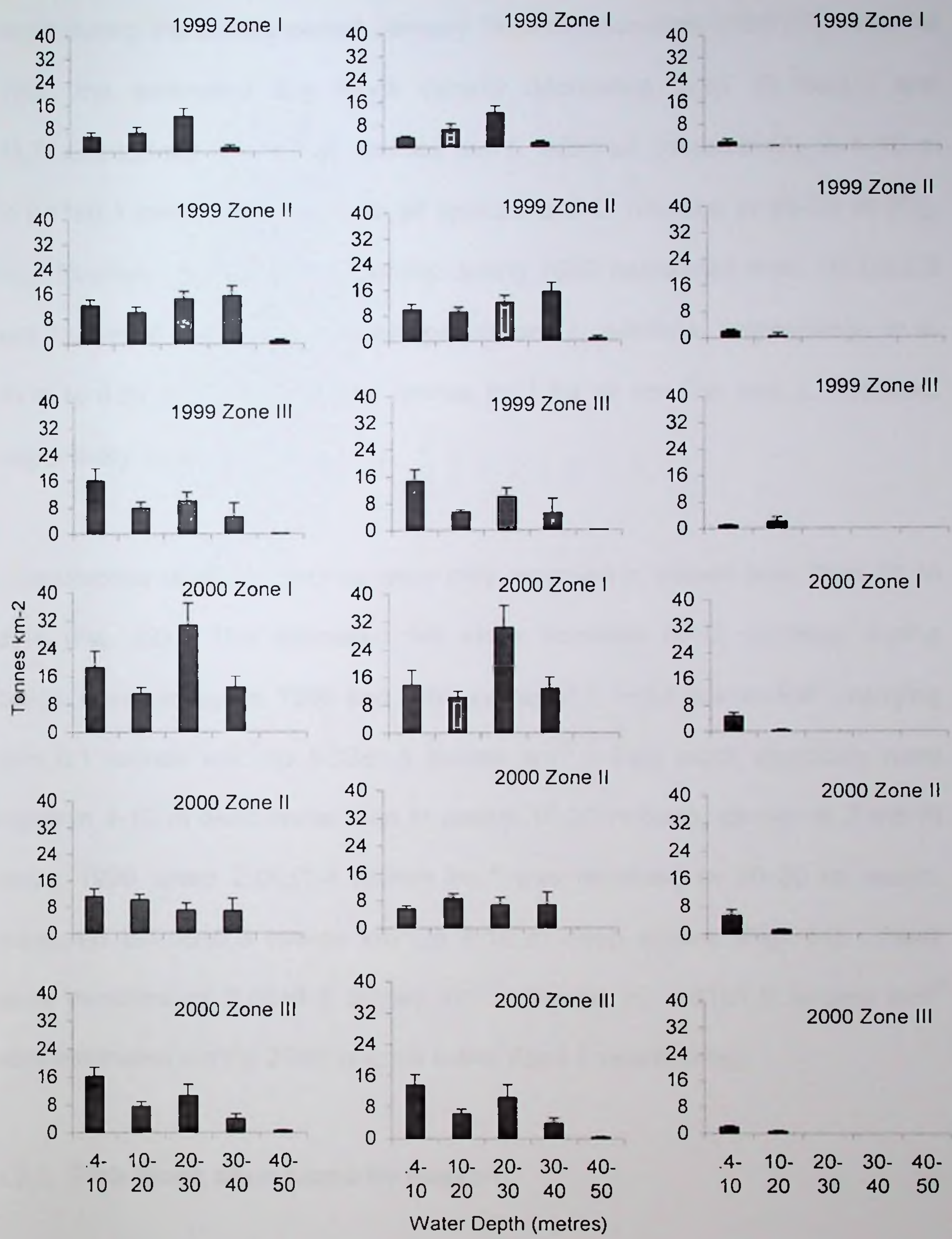


Figure 14. Standing crop (tonnes km^{-2}) of fish caught by water depth during bottom trawl surveys in the Uganda sector ofLake Victoria between January 1999 and December 2000. . [All fish species (Left), Lates niloticus (Middle), and *Oreochromis niloticus* (Right)].

The estimated abundance of fish in Zone III decreased with increasing water depth during the survey period January 1999 to December 2000 (Fig. 14). In 1999, the estimated fish stock density decreased from 16.38±3.5 and 14.77±3.3 tonnes km^{-2} for all species and *L. niloticus*, respectively, in 4-10 m to 0.11±0.1 tonnes km^{-2} for both all species and *L. niloticus* in 40-50 m (Fig. 14). Similarly, the fish stock density during 2000 decreased from 16.19±2.6 and 13.69±2.6 tonnes km^{-2} for all species and *L. niloticus*, respectively, in 4-10 m to 0.62±0.2 and 0.54±0.2 tonnes km^{-2} for all species and *L. niloticus*, respectively, in 40-50 m (Fig. 14).

Oreochromis niloticus catches were only recorded in waters less than 20 m deep (Fig. 12). The estimated fish stock densities of *O. niloticus* during bottom trawl surveys in 1999 and 2000 averaged 1.1±0.4 tonnes km^{-2}, ranging from 0.1 tonnes km^{-2} to 5.33±1.8 tonnes km^{-2}. Fish stock densities were higher in 4-10 m deep water than in waters 10-20 m deep, except in Zone III during 1999 when 2.09±1.4 tonnes km^{-2} was recorded in 10-20 m waters compared to1.05±0.3 tonnes km^{-2} in 4-10 m deep waters (Fig. 14). Peak stock densities of 5.33±1.8 tonnes km^{-2} followed by 4.81±1.0 tonnes km^{-2} were estimated during 2000 in Zone II and Zone I, respectively.

4.2.2. **Fish stock abundance by season**

The stock densities of fish caught from bottom trawl surveys varied with seasons and zones (Fig. 15) (details in Appendix 9). The highest catches of

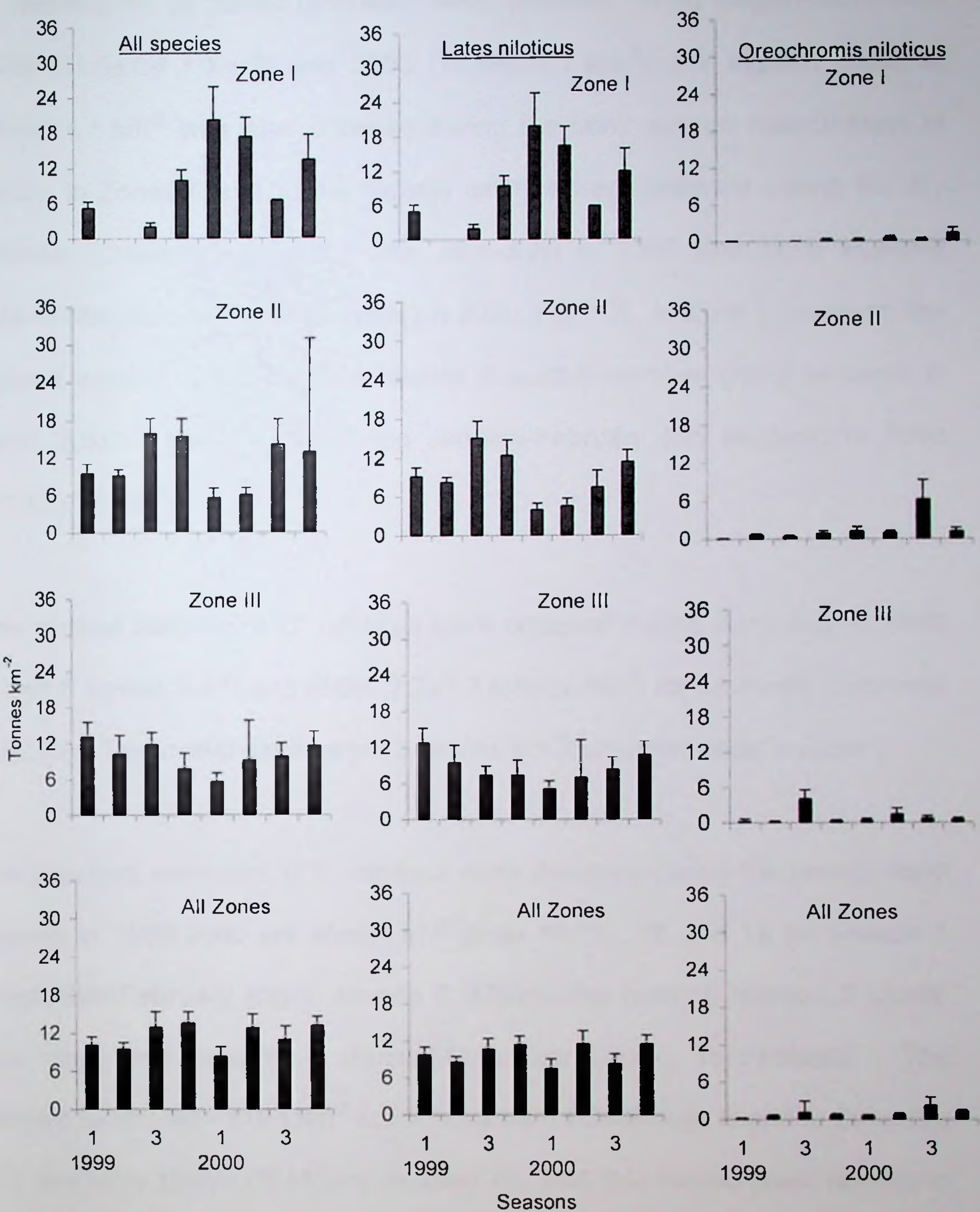


Figure 15 . Standing crop (tonnes km^{-2}) of fish caught by season during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000. All fish species (Left), *Lates niloticus* (Middle), and *Oreochromis niloticus* (Right).[Seasons: 1 = December-February (dry), 2 = March-May (rainy), 3 = June-July (dry), 4 = August-November (rainy)]

L. niloticus for all zones combined were obtained during August-November 1999 (11.5±1.4 t km^{-2}) and 2000 (11.6±1.4 t km^{-2}); the highest catch of 11.6±2.4 t km^{-2} was also obtained during the rainy season (March-May) in 2000. In Zones II and III the highest catches were obtained during the dry seasons (December-February and June-July) in 1999 and rainy seasons (March-May and August-November) in 2000 (Fig. 15). In Zone I, however, the highest catches were obtained during August-November (rainy season) in 1999 (9.5±1.7 t km^{-2}) and during January-February (dry season) in 2000 (19.8±5.7 t km^{-2}).

The highest catches of *O. niloticus* were obtained during June-July in 1999 (1.2±1.8 tonnes km^{-2}) and 2000 (2.2±1.3 tonnes km^{-2}) for all zones combined (Fig. 15). The lowest catches (<1.5 tonnes km^{-2}) were recorded in Zone I.

The seasonal variations of *L. niloticus* stock densities during the bottom trawl surveys in 1999-2000 are shown in Figures 16, 17, 18 and 19 for season 1 (December-February (dry)), season 2 (March-May (rainy)), season 3 (June-July (dry)) and season 4 (August-November (rainy), respectively. The habitats (grids) with >10 t km^{-2} *L. niloticus* were B08 (Mvuja Island in Zone III), B10 (Berkeley Bay – off Majanji in Zone III), C04 (Mu-Kitobo-Buvu Islands in Zone II), D02 (White stony-Bale in Zone I), D04 (Lutoboka Channel in Zone II), E02 (Dimo area in Zone I), E03 (Lujabwa island area in Zone I) and F02 Masambwa-Lujabwa in Zone I) (details in Appendix 10).. The peak catches of *L. niloticus* in most of these areas were obtained during March-May and August-November, both rainy seasons.

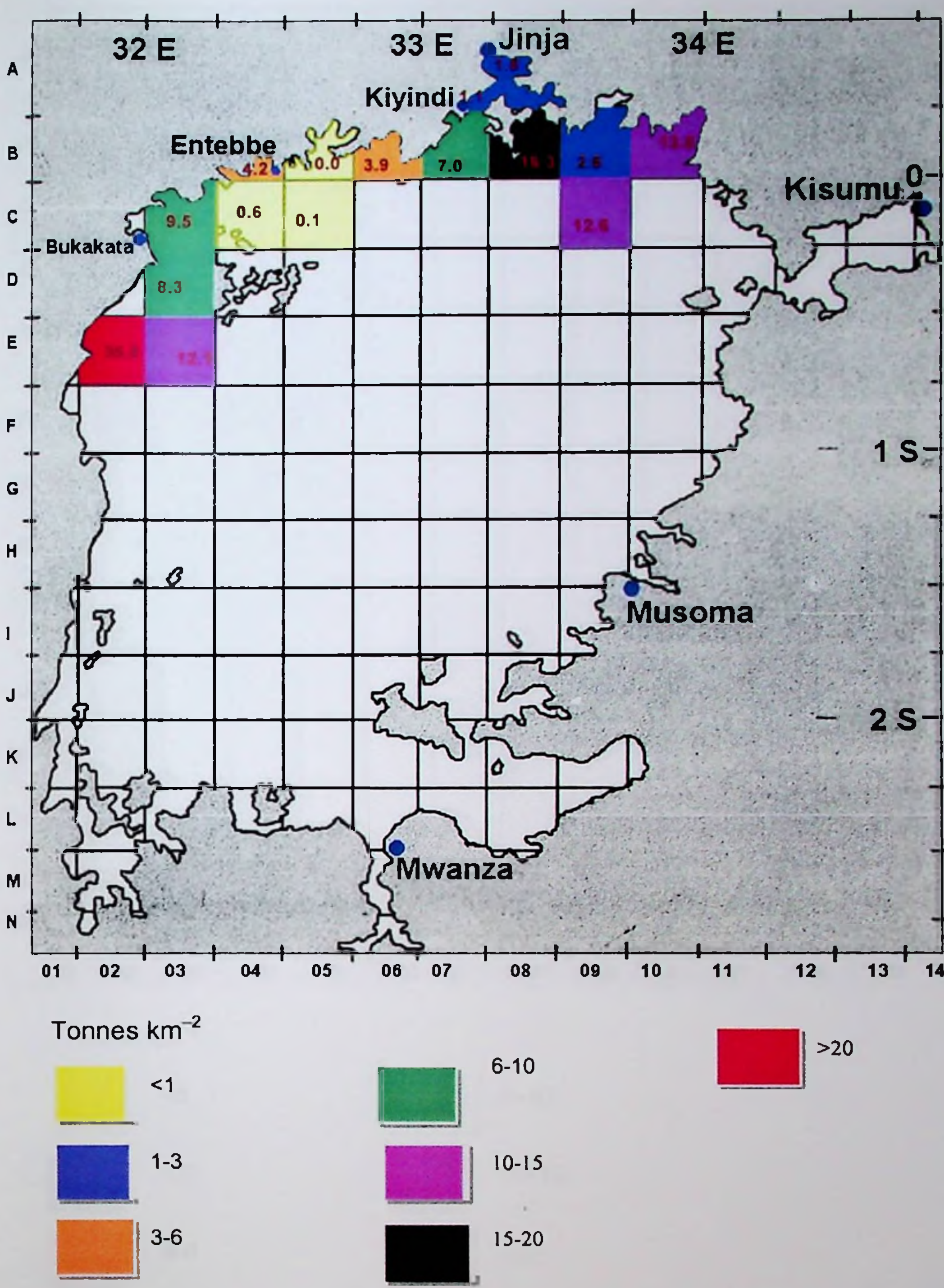


Figure 16. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Lates niloticus* caught during bottom trawl surveys in the Uganda sector, during season 1 (December-February (dry)) of 1999 and 2000.

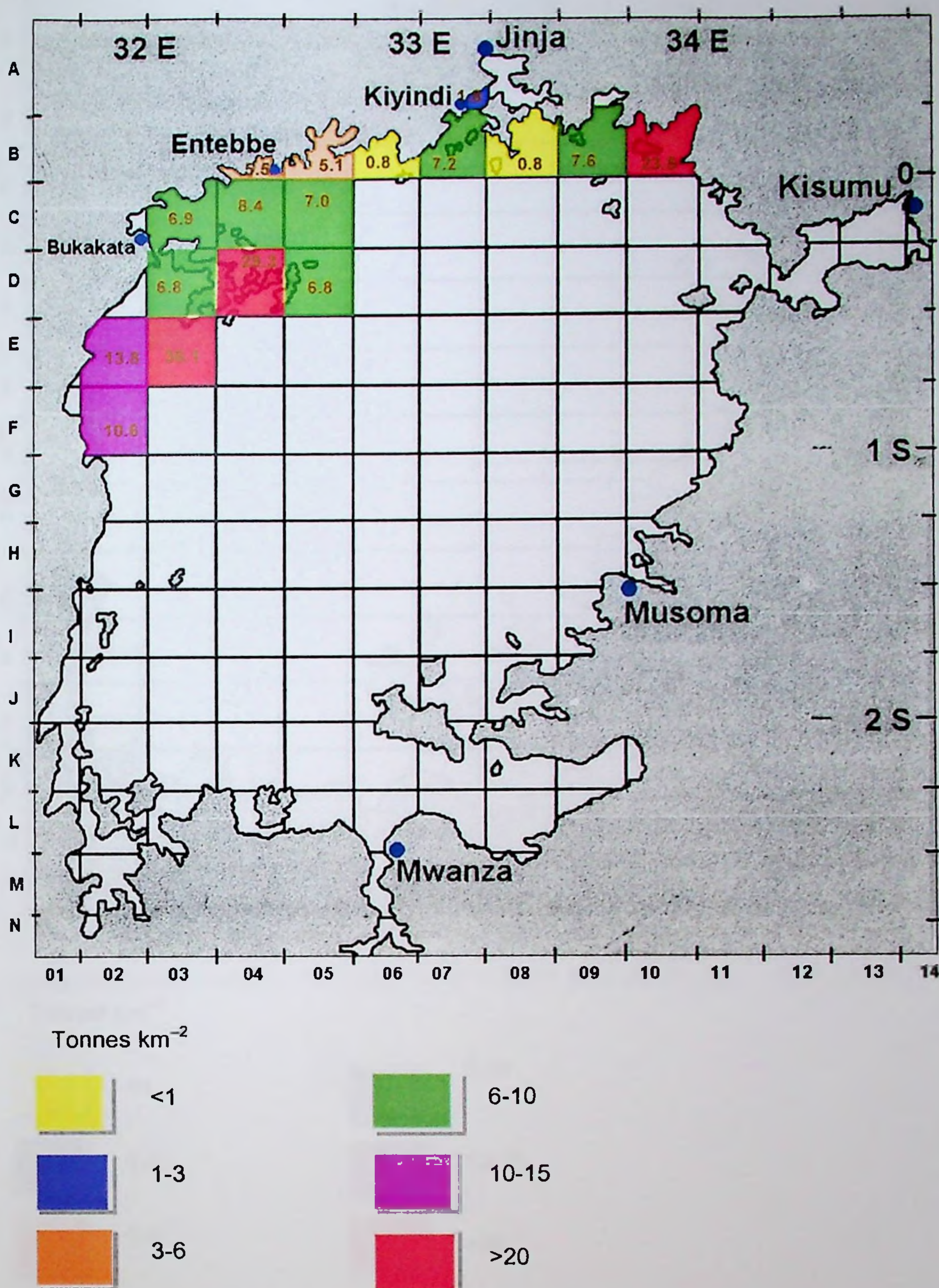


Fig. 17. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Lates niloticus* caught during bottom trawl surveys in Uganda waters, during season 2 (March-May (rainy)) of 1999 and 2000.

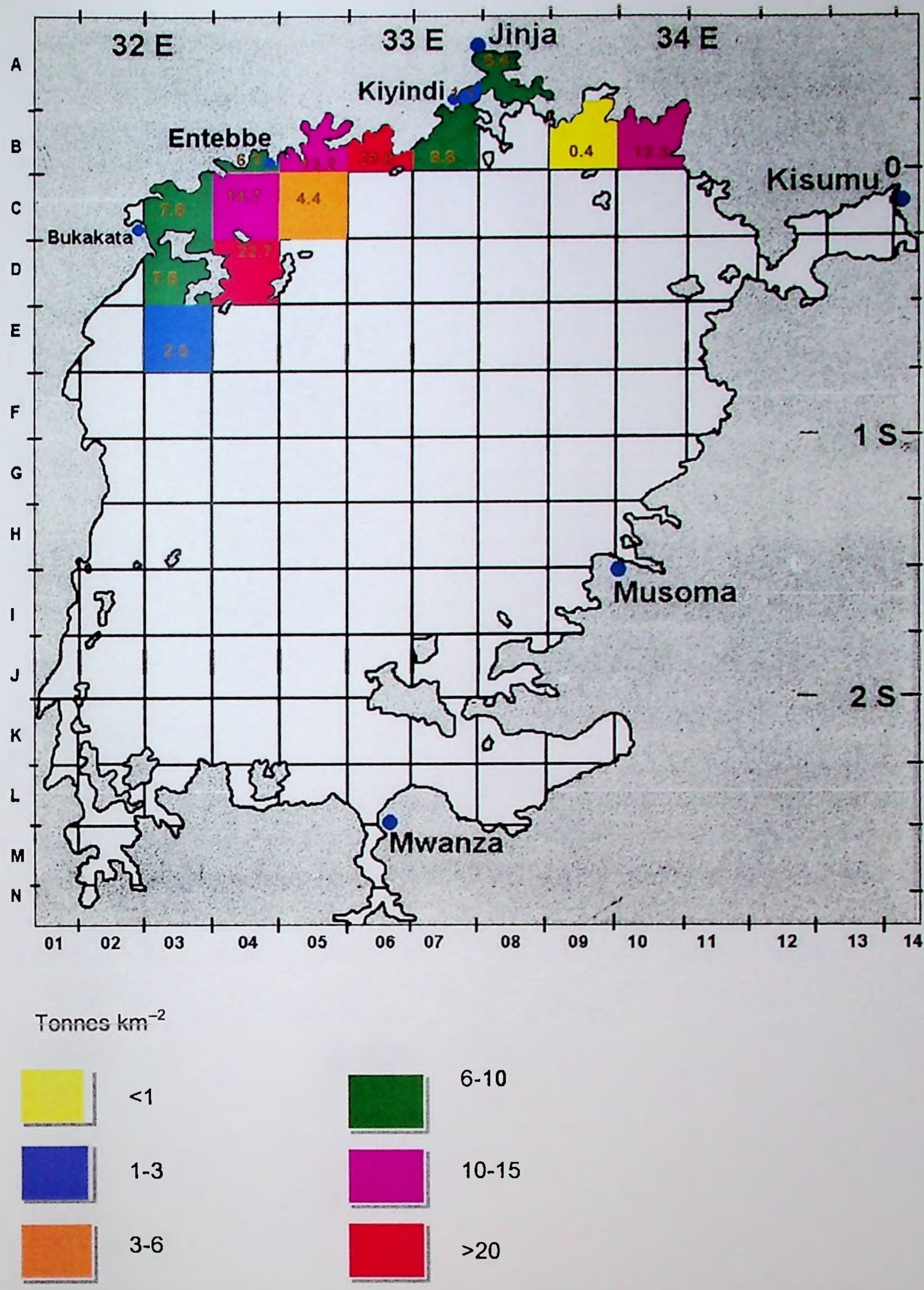


Fig 18. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Lates niloticus* caught during bottom trawl surveys in the Uganda waters, during season 3 (June-July (dry)) of 1999 and 2000.

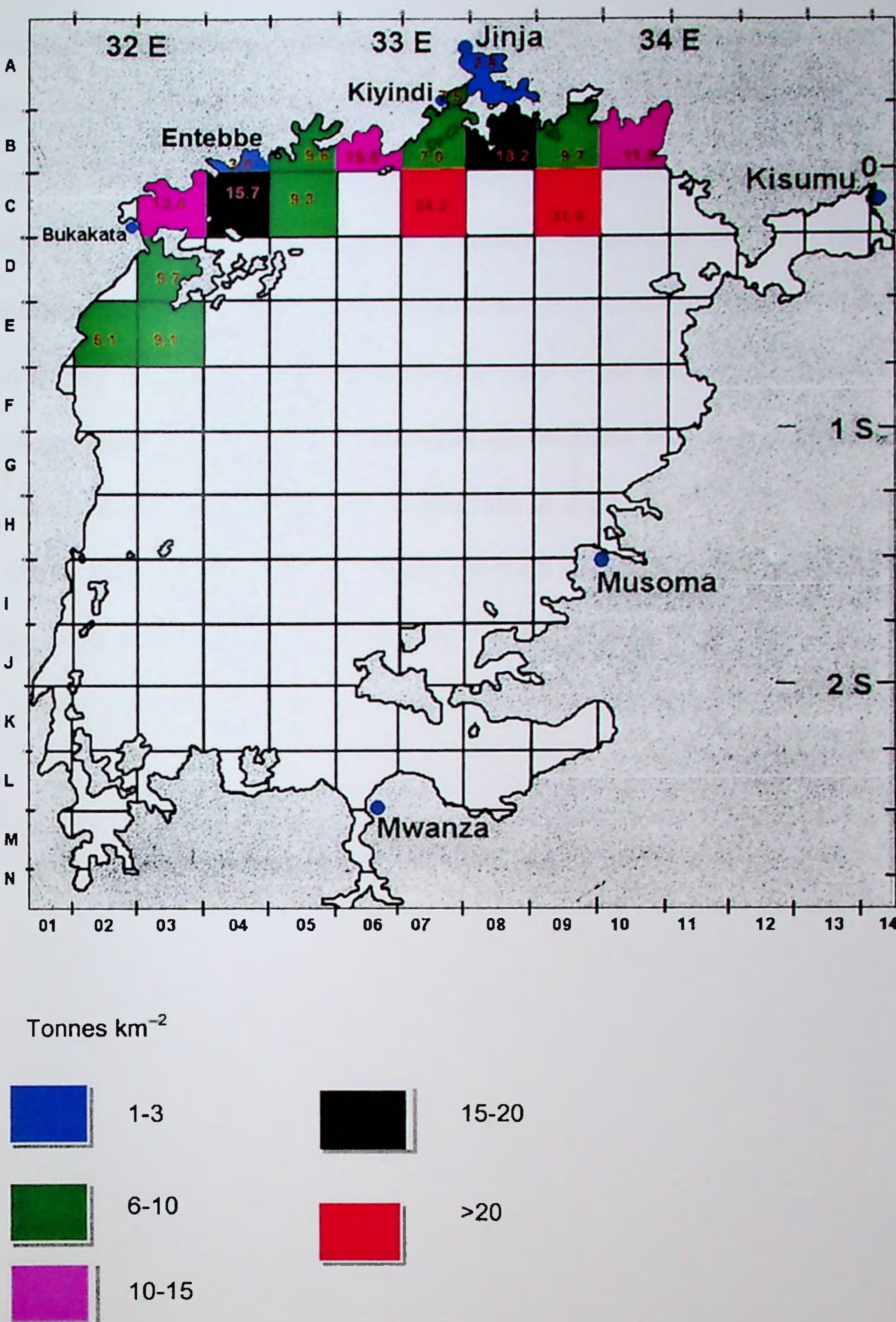


Fig. 19. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Lates niloticus* caught during bottom trawl surveys in the Uganda waters, during season 4 (August-November (rainy)) of 1999 and 2000.

Similarly, the seasonal variations of *O. niloticus* stock densities during the bottom trawl surveys in 1999-2000 are shown in Figures 20, 21, 22 and 23 for season 1 (December-February (dry)), season 2 (March-May (rainy)), season 3 (June-July (dry)) and season 4 (August-November (rainy), respectively (details in Appendix 10). The areas with fish catches >1 t km^{-2} were B07 (Itome Bay in Zone III), B10 (Berkeley Bay – off Majanji in Zone III), C03 (Bunjako Bay/Off Mouth of River Katonga in Zone II), C04 (Mu-Kitobo-Buvu Islands in Zone II), D02 (White stony-Bale in Zone I) and D03 (Bomangi Bay in Ssese Islands in Zone II). Peak catches of *O. niloticus* in most of these areas were obtained during June-July, the dry season (Fig. 22).

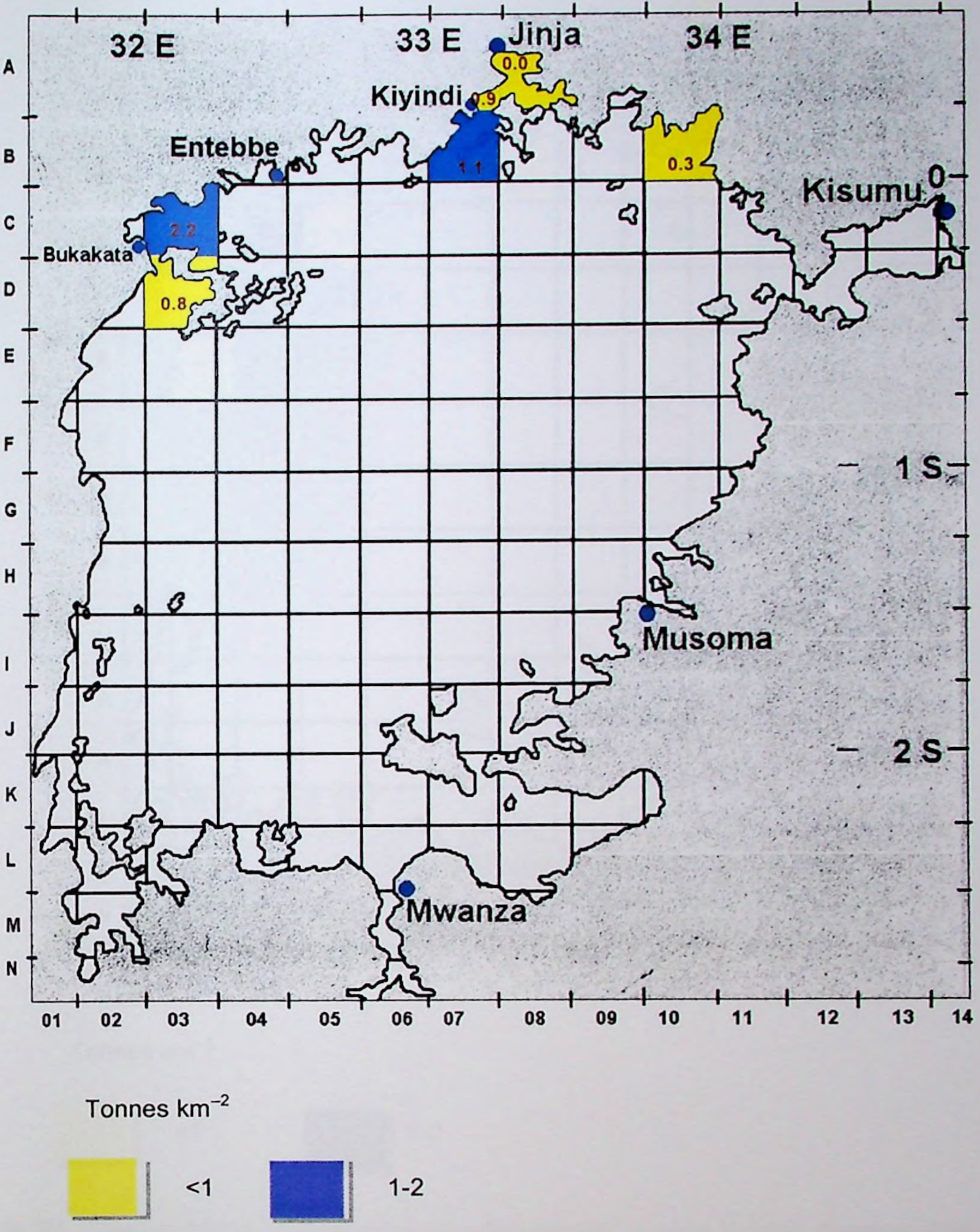


Fig. 20. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Oreochromis niloticus* caught during bottom trawl surveys in Uganda waters, during season 1 (December-February (dry)) of 1999 and 2000.

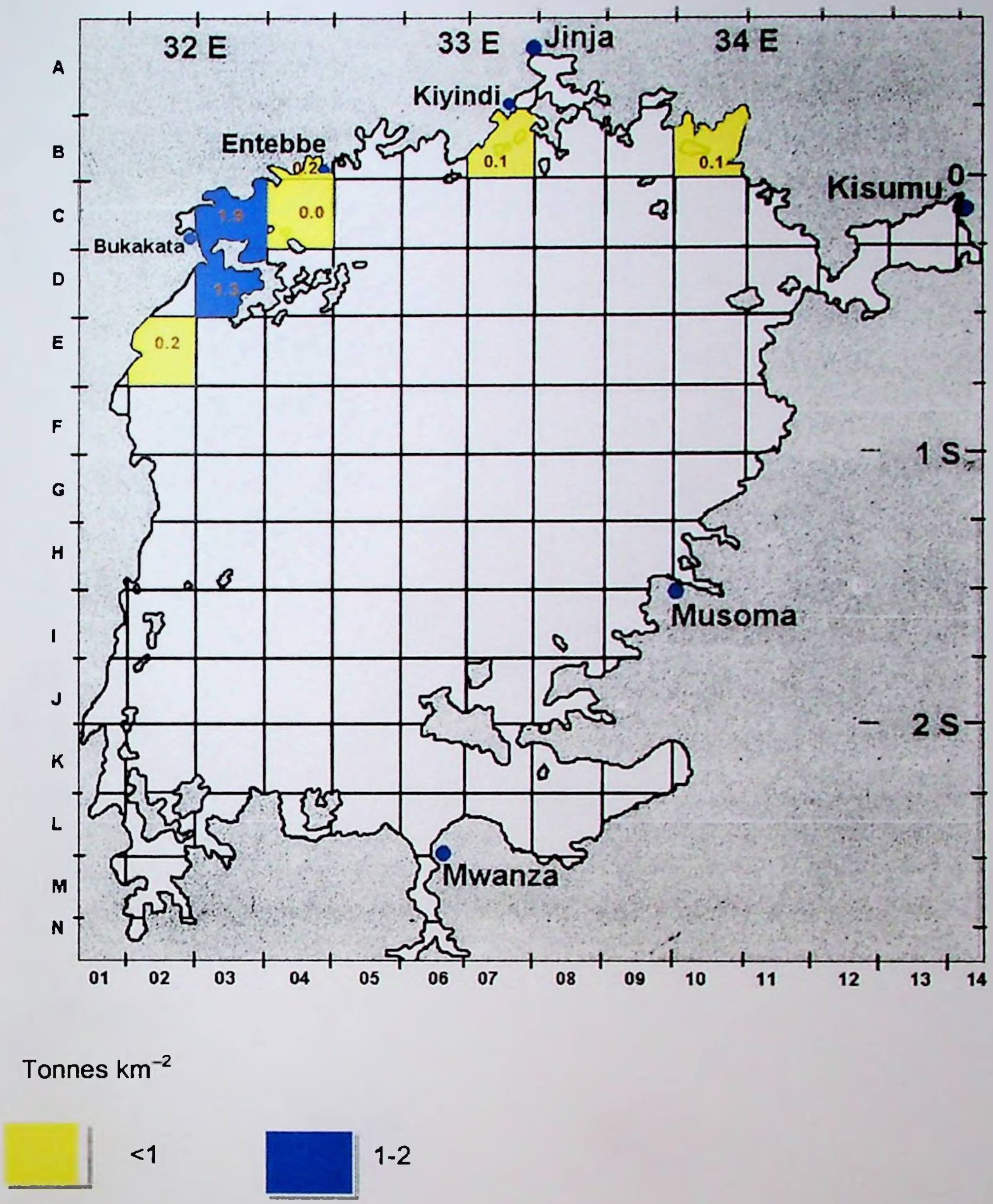


Fig. 21. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda waters, during season 2 (March – May (rainy)) of 1999 and 2000.

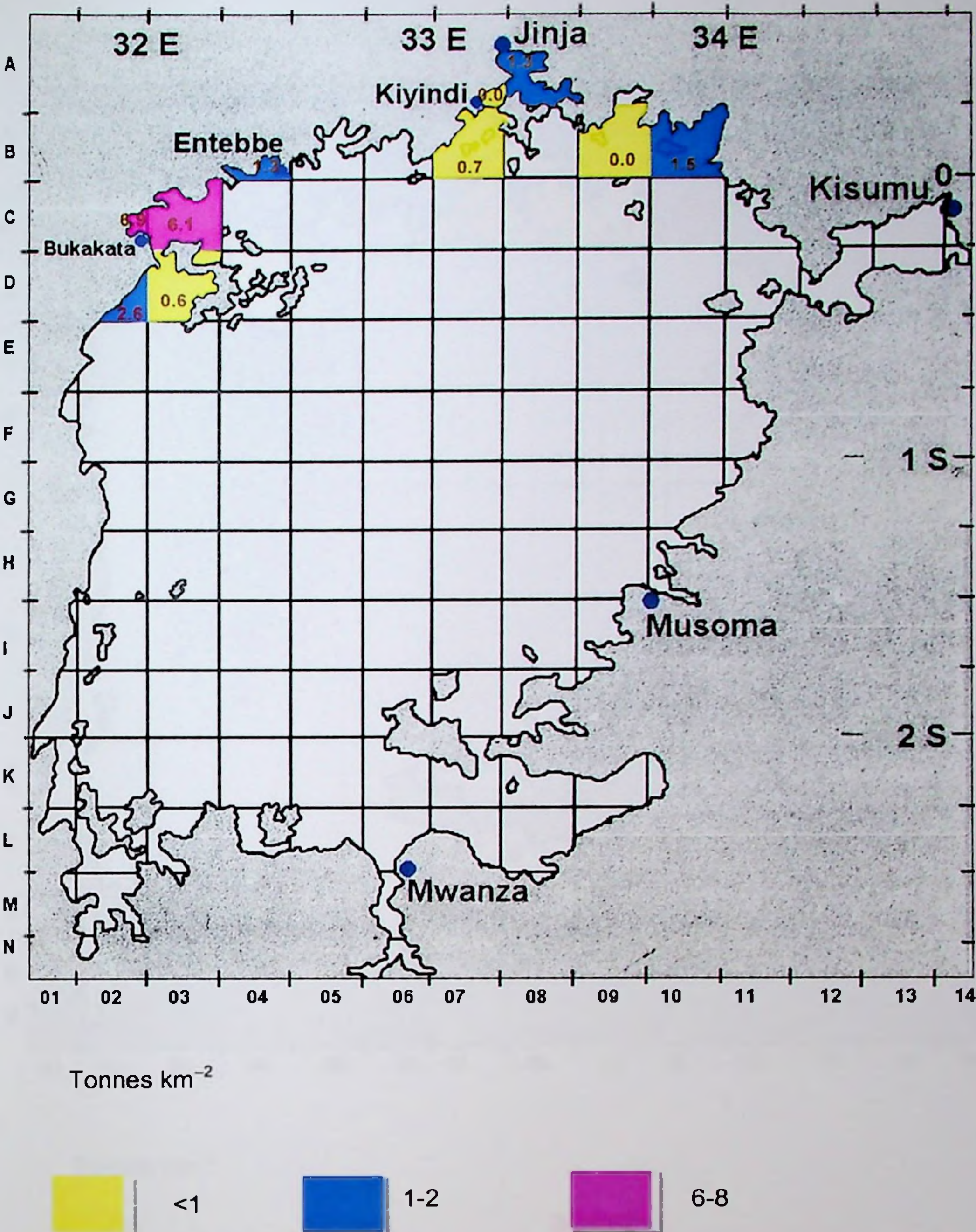


Fig. 22. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda waters, during season 3 (June-July (dry)) of 1999 and 2000.

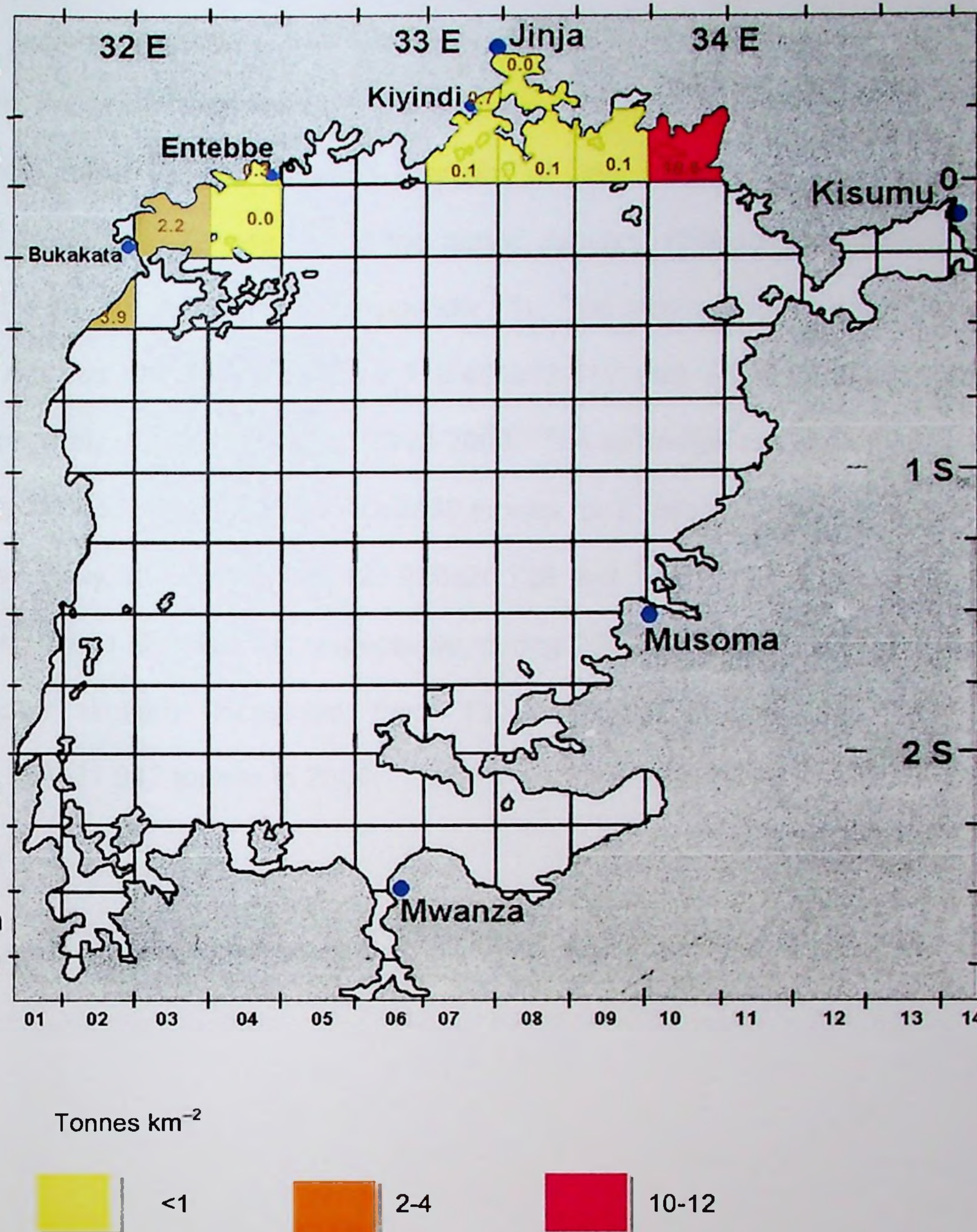


Fig. 23. Chart of 15x15 nautical miles sampling squares in Lake Victoria showing index of abundance (tonnes km^{-2}) for *Oreochromis niloticus* caught during bottom trawl surveys in Uganda waters, during season 4 (August- November (rainy)) of 1999 and 2000.

4.3. **Fish biomass**

From the swept area method, the biomass for all fish species in the 4-40 m depth zone in the Uganda portion of the lake was estimated at 136 562±13 412 tonnes during the period January 1999 to December 2000 (Table 20, Fig. 24) (details in Appendix 11). The biomass for *L. niloticus* and *O. niloticus* were estimated at 119 491±13 412 and 12 193±3658 tonnes, respectively, during the period 1999-2000. The estimated biomass increased from 117 053±15 851 and 7316±2439 tonnes for *L. niloticus* and *O. niloticus*, respectively, during 1999 to 121 930±20 728 and 17 070±7316 tonnes for *L. niloticus* and *O. niloticus*, respectively, during 2000. The biomass for all fish species similarly increased from 130 465±17 070 tonnes in 1999 to 142 058±21 947 tonnes in 2000.

Table 20. Abundance of fish stocks (tonnes) during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and. December 2000.

Period	Water Depth Interval (m)	Estim. area (km^{-2})	No. of Hauls	Biomass (tonnes±95% Conf. limits)		
				All species	*L. niloticus*	*O. niloticus*
1999	4-10	3744	49	50170±12730	42307±11981	6365±2246
	10-20	3584	99	29030±6451	25446±5734	2150±1075
	20-30	2842	80	34957±8810	32683±8242	
	30-40	2025	24	21668±9923	21263±9720	
	4-40	12193	252	130465±17070	117053±15851	7316±2439
2000	4-10	3744	56	50918±13478	33322±9734	16099±9360
	10-20	3584	99	34048±6810	29747±6810	2867±1075
	20-30	2842	56	39504±15347	38935±15347	
	30-40	2025	19	21870±10125	21263±10328	
	4-40	12193	230	142658±21947	121930±20728	17070±7316
1999	4-10	3744	105	50544±24386	37440±24386	11606±4867
-2000	10-20	3584	198	31539±4301	27597±4301	2509±717
	20-30	2842	136	36946±7958	35809±7958	
	30-40	2025	43	21668±6683	21263±6683	
	4-40	12193	482	136562±13412	119491±13412	12193±3658

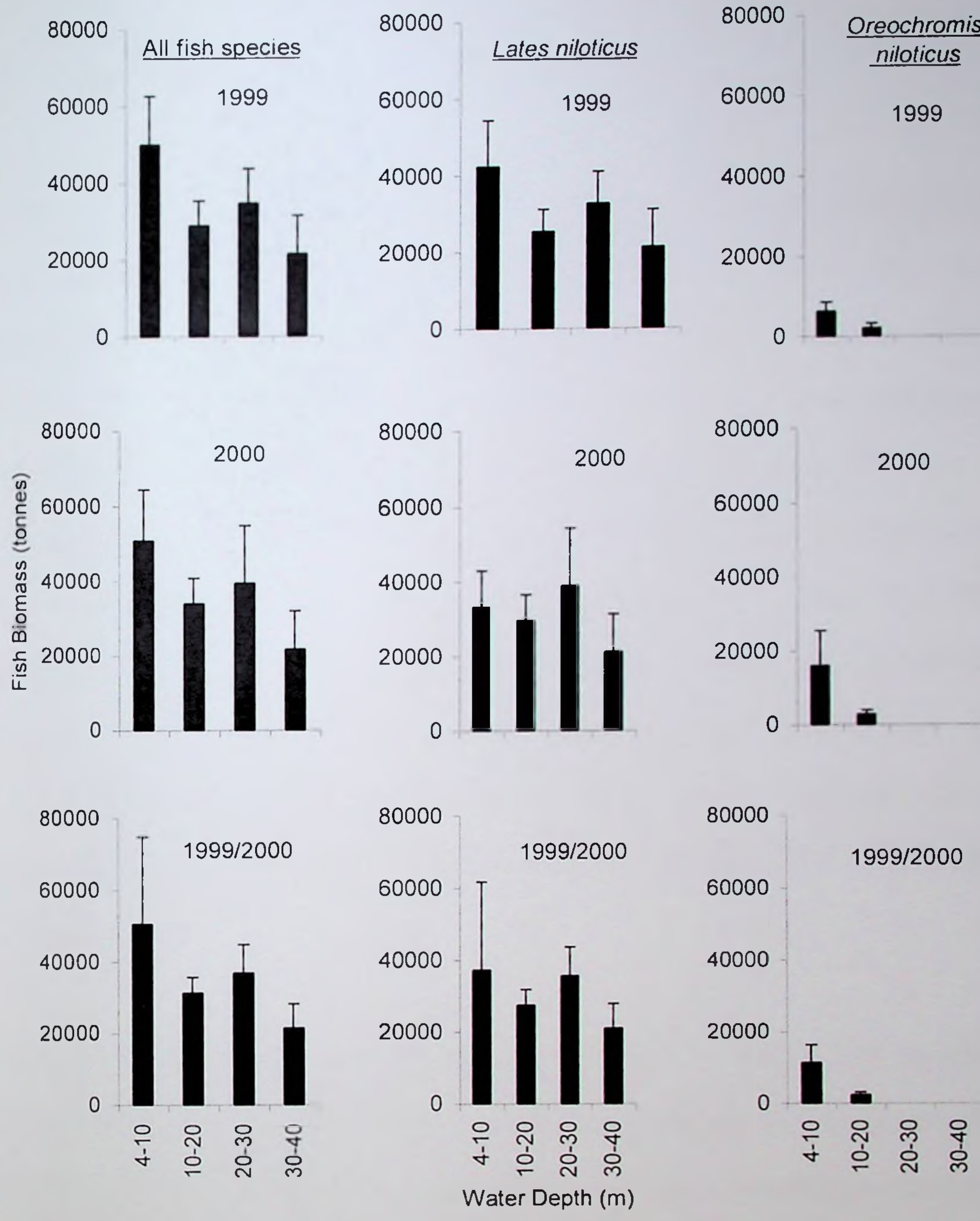


Fig. 24. Abundance (tonnes) of fish stocks during bottom trawl surveys in the Uganda sector of Lake Victoria, January 1999 to December 2000.
[All fish species (Left), *Lates niloticus* (Middle), and *Oreochromis niloticus* (Right)].

4.4. **Fish population structure**

4.4.1. *Lates niloticus*

A total of 291 751 fish of *L. niloticus* measuring 2-183 cm total length (TL) were analysed for length frequency distribution in terms of numbers and weight (Table 21, Fig. 25). Numerically, 82.26% of the fish measured less than 30 cm TL (weighing <300 g individually); 66.47% of the fish measured less than 20 cm TL (weighing <90 g). The fish measuring 20-59 cm TL contributed the bulk of the catch by weight (78.44%) while 33.97% of the catch (by weight) was from fish measuring 40-49 cm TL (Table 21). The harvestable fish, measuring at least 50 cm TL, contributed 27.47% of the fish during the survey period 1999-2000 (Table 21) (details in Appendix 12). Accordingly, about 32 800 tonnes of the 119 491 tonnes estimated for *L. niloticus* in the 4-40 m depth zones during the survey period 1999-2000 were harvestable fish.

The bulk of the immature *L. niloticus* were caught in waters <20 m deep (63.36 % by numbers) and in Zone III where they (immature fish) contributed 99.02%, 98.85% and 99.38% of the catch (by numbers) during 1999-2000, 1999 and 2000, respectively.

Table 21. Population structure of *Lates niloticus* caught during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Total Length (cm)	Percentage (numbers)	Percentage (weight)	Estimated Biomass (tonnes)
2-10	33.79	0.63	753
10-20	32.68	5.32	6357
20-30	15.79	12.49	14924
30-40	8.74	20.12	24042
40-50	7.06	33.97	40591
50-60	1.35	11.86	14172
60-70	0.29	4.32	5162
70-80	0.13	3.23	3860
80-90	0.09	3.23	3860
90-100	0.05	2.52	3011
100-110	0.02	1.04	1243
110-120	0.01	0.57	681
120-130	0.00	0.08	96
130-190	0.00	0.62	741
Total			119491

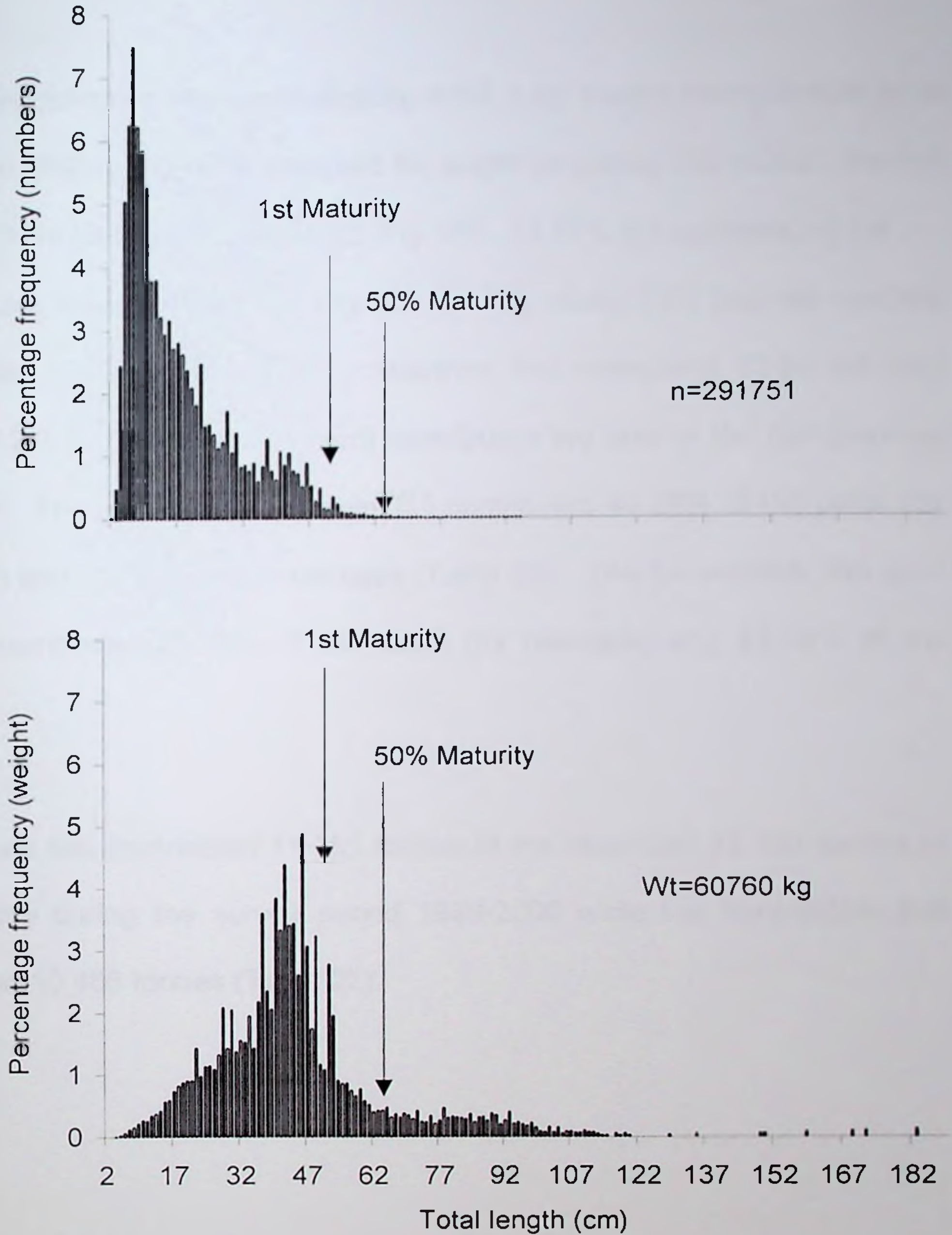


Figure 25. Length frequency distribution of *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
(Indicated maturity stages are for male fish)

4.4.2. *Oreochromis niloticus*

11 762 *Oreochromis niloticus* (weighing 6384.1 kg) caught during bottom trawl surveys in 1999-2000 were analysed for length frequency distribution; the fish were 3-69 cm total length (Table 22, Fig. 26). 72.77% (by numbers) of the fish had not reached 50% maturity (27 cm TL); about 60% had not reached size at first maturity (22 cm TL). However, fish measuring 37-51 cm total length (1.2-3.2 kg individual weight) contributed the bulk of the fish biomass (62.38%). The mature fish (≥22 cm TL) contributed 40.26% of the catch (by numbers) and 93.18% of the biomass (Table 22). The harvestable fish (≥27 cm TL) composed 27.23% of the catch (by numbers) and 85.84% of the biomass.

The mature fish contributed 11 361 tonnes of the estimated 12 193 tonnes of *O. niloticus* during the survey period 1999-2000 while the harvestable fish composed 10 466 tonnes (Table 22).

Table 22. Population structure of *Oreochromis niloticus* caught during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Total Length (cm)	Percentage (numbers)	Percentage (weight)	Estimated Biomass (tonnes)
2-7	13.59	0.09	11
7-12	18.37	0.56	68
12-17	13.33	1.52	185
17-22	14.45	4.65	567
22-27	13.03	7.34	895
27-32	3.72	3.86	471
32-37	4.96	8.95	1091
37-42	6.31	16.83	2052
42-47	7.07	26.55	3237
47-52	3.74	19.00	2317
52-57	1.06	7.03	857
57-62	0.26	2.30	280
62-67	0.08	0.85	104
67-72	0.03	0.47	57
Total			12193

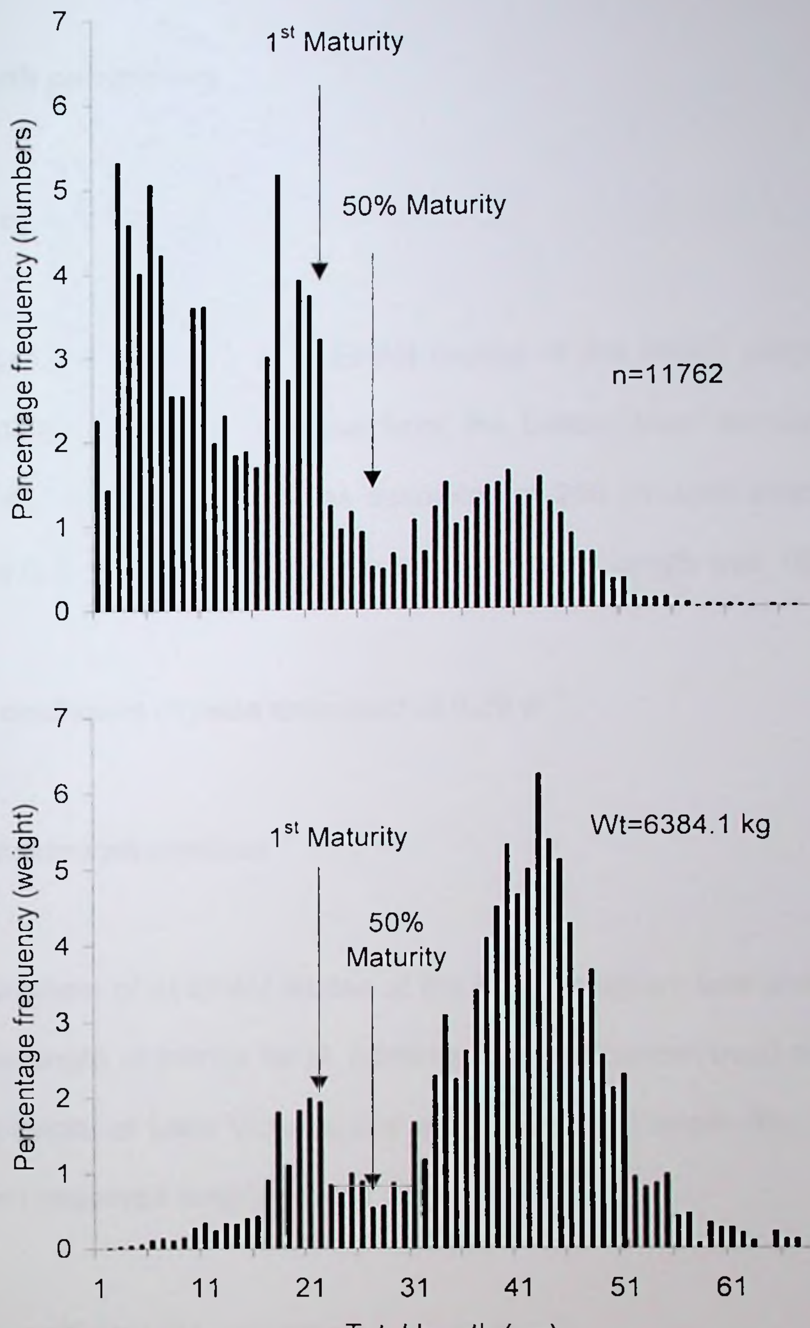


Figure 26. Length frequency distribution of *Oreochromis niloticus* caught during bottomtrawl surveys in the Uganda portion of Lake Victori; between January 1999 and December 2000.

4.5. **Fish stock assessment and biological parameters**

4.5.1. **Growth parameters**

4.5.1.1. *Lates niloticus*

From the response analysis of ELEFAN routine of the FiSAT program, the length at infinity (L_∞) for *L. niloticus* from the bottom trawl surveys in the Uganda sector of Lake Victoria was estimated at 256 cm total length (Rn = Goodness of fit index = 0.967); the maximum observed length was 183 cm.

The growth coefficient (K) was estimated at 0.29 yr^{-1}.

4.5.1.2. *Oreochromis niloticus*

Response analysis of ELEFAN routine of the FiSAT program was also used to estimate the length at infinity for *O. niloticus* from the bottom trawl surveys in the Uganda sector of Lake Victoria; this was 75 cm total length (Rn = 0.950); the maximum observed length was 69 cm.

The growth coefficient (K) was estimated at 0.40 yr^{-1}.

4.5.2. **Size at maturity**

4.5.2.1. *Lates niloticus*

The regress results for *L. niloticus* caught in bottom trawls between January 1999 and December 2000 are shown in Table 23 for males and Table 24 for females. During the 1999-2000 surveys, the size at first maturity (L_m) of male and female *L. niloticus* was estimated at 50.0 and 64.0 cm total length, respectively (Fig. 27). The size at 50% maturity (L_{m50}) was 64.0 and 73.0 cm total length for male and female *L. niloticus*, respectively (Fig. 27).

4.5.2.2. *Oreochromis niloticus*

The regress results for *O. niloticus* caught in bottom trawls between January 1999 and December 2000 are shown in Table 25 for males and Table 26 for females. During the 1999-2000 surveys, the size at first maturity (L_m) of male and female *O. niloticus* was estimated at 21.5 and 22.5 cm total length, respectively (Figs 28 & 29). The size at 50% maturity (L_{m50}) was 27.1 and 26.8 cm total length for male and female *O. niloticus*, respectively (Figs 28 & 29).

Table 23. Regression results for male *Lates niloticus* caught in bottom trawls in the Uganda sector of Lake Victoria between January 1999 to December 2000

a	b	ssq	L50
9.128422	0.142438	0.206948	**64.08713**

Males 1999&2000

	Immature Bin	Frequency	Mature Bin	Frequency	Total	Obser	Pred	ssq
11.5	11.5	15	11.5	0	15	0	0.000558	3.11E-07
14.5	14.5	136	14.5	0	136	0	0.000855	7.32E-07
17.5	17.5	173	17.5	0	173	0	0.001311	1.72E-06
20.5	20.5	151	20.5	0	151	0	0.002008	4.03E-06
23.5	23.5	142	23.5	0	142	0	0.003076	9.46E-06
26.5	26.5	116	26.5	0	116	0	0.004708	2.22E-05
29.5	29.5	111	29.5	0	111	0	0.0072	5.18E-05
32.5	32.5	110	32.5	0	110	0	0.010996	0.000121
35.5	35.5	103	35.5	0	103	0	0.01676	0.000281
38.5	38.5	120	38.5	1	121	0.008264	0.025467	0.000296
41.5	41.5	106	41.5	0	106	0	0.038521	0.001484
44.5	44.5	88	44.5	2	90	0.022222	0.05787	0.001271
47.5	47.5	77	47.5	1	78	0.012821	0.086067	0.005365
50.5	50.5	57	50.5	8	65	0.123077	0.126163	9.52E-06
53.5	53.5	44	53.5	10	54	0.185185	0.181234	1.56E-05
56.5	56.5	32	56.5	10	42	0.238095	0.253375	0.000233
59.5	59.5	27	59.5	13	40	0.325	0.342228	0.000297
62.5	62.5	14	62.5	7	21	0.333333	0.443723	0.012186
65.5	65.5	4	65.5	11	15	0.733333	0.550142	0.033559
68.5	68.5	5	68.5	19	24	0.791667	0.652163	0.019461
71.5	71.5	5	71.5	9	14	0.642857	0.741901	0.00981
74.5	74.5	2	74.5	14	16	0.875	0.815053	0.003594
77.5	77.5	2	77.5	11	13	0.846154	0.871075	0.000621
80.5	80.5	3	80.5	16	19	0.842105	0.91196	0.00488
83.5	83.5	2	83.5	4	6	0.666667	0.940762	0.075128
86.5	86.5	0	86.5	7	7	1	0.960549	0.001556
89.5	89.5	0	89.5	6	6	1	0.97391	0.000681
92.5	92.5	0	92.5	9	9	1	0.982826	0.000295
95.5	95.5	1	95.5	4	5	0.8	0.988731	0.035619
98.5	98.5	0	98.5	6	6	1	0.992621	5.45E-05
101.5	101.5	0	101.5	4	4	1	0.995174	2.33E-05
104.5	104.5	0	104.5	1	1	1	0.996847	9.94E-06
107.5	107.5	0	107.5	1	1	1	0.997941	4.24E-06
110.5	110.5	0	110.5	2	2	1	0.998656	1.81E-06
113.5	113.5	0	113.5	4	4	1	0.999123	7.69E-07
116.5	116.5	0	116.5	1	1	1	0.999428	3.27E-07
128.5	128.5	0	128.5	1	1	1	0.999896	1.07E-08
131.5	131.5	0	131.5	0	0	#DIV/0!	0.999932	#DIV/0!
134.5	134.5	0	134.5	0	0	#DIV/0!	0.999956	#DIV/0!
137.5	137.5	0	137.5	0	0	#DIV/0!	0.999971	#DIV/0!
140.5	140.5	0	140.5	0	0	#DIV/0!	0.999981	#DIV/0!
143.5	143.5	0	143.5	0	0	#DIV/0!	0.999988	#DIV/0!
146.5	146.5	0	146.5	0	0	#DIV/0!	0.999992	#DIV/0!
149.5	149.5	0	149.5	0	0	#DIV/0!	0.999995	#DIV/0!
152.5	152.5	0	152.5	0	0	#DIV/0!	0.999997	#DIV/0!
155.5	155.5	0	155.5	0	0	#DIV/0!	0.999998	#DIV/0!
158.5	158.5	0	158.5	0	0	#DIV/0!	0.999999	#DIV/0!
161.5	161.5	0	161.5	0	0	#DIV/0!	0.999999	#DIV/0!
164.5	164.5	0	164.5	0	0	#DIV/0!	0.999999	#DIV/0!
167.5	167.5	0	167.5	0	0	#DIV/0!	1	#DIV/0!
170.5	170.5	0	170.5	0	0	#DIV/0!	1	#DIV/0!
173.5	173.5	0	173.5	0	0	#DIV/0!	1	#DIV/0!
	More	0	More	0	0	#DIV/0!	0.000109	#DIV/0!

Table 24. Regression results for female *Lates niloticus* caught in bottom trawls in the Uganda sector of Lake Victoria between January 1999 and December 2000

Females	a	b	ssq	L50
	11.94459	0.161639	0.146743	**73.89682**

	Immature Bin	Frequency	Mature Bin	Frequency	Total	Obser	Pred	ssq
11.5	11.5	5	11.5	0	5	0	4.17E-05	1.74E-09
14.5	14.5	15	14.5	0	15	0	6.77E-05	4.58E-09
17.5	17.5	26	17.5	0	26	0	0.00011	1.21E-08
20.5	20.5	45	20.5	0	45	0	0.000178	3.18E-08
23.5	23.5	38	23.5	0	38	0	0.00029	8.4E-08
26.5	26.5	42	26.5	0	42	0	0.000471	2.21E-07
29.5	29.5	40	29.5	0	40	0	0.000764	5.84E-07
32.5	32.5	39	32.5	0	39	0	0.00124	1.54E-06
35.5	35.5	44	35.5	0	44	0	0.002012	4.05E-06
38.5	38.5	43	38.5	0	43	0	0.003264	1.07E-05
41.5	41.5	27	41.5	0	27	0	0.00529	2.8E-05
44.5	44.5	28	44.5	0	28	0	0.008563	7.33E-05
47.5	47.5	24	47.5	0	24	0	0.013833	0.000191
50.5	50.5	14	50.5	0	14	0	0.022274	0.000496
53.5	53.5	22	53.5	0	22	0	0.035677	0.001273
56.5	56.5	18	56.5	0	18	0	0.056679	0.003213
59.5	59.5	9	59.5	1	10	0.1	0.088905	0.000123
62.5	62.5	9	62.5	2	11	0.181818	0.136795	0.002027
65.5	65.5	8	65.5	1	9	0.111111	0.204687	0.008757
68.5	68.5	5	68.5	2	7	0.285714	0.294769	8.2E-05
71.5	71.5	2	71.5	4	6	0.666667	0.404339	0.068816
74.5	74.5	8	74.5	5	13	0.384615	0.524355	0.019527
77.5	77.5	2	77.5	4	6	0.666667	0.641623	0.000627
80.5	80.5	3	80.5	4	7	0.571429	0.744089	0.029812
83.5	83.5	1	83.5	7	8	0.875	0.825238	0.002476
86.5	86.5	1	86.5	7	8	0.875	0.884644	9.3E-05
89.5	89.5	0	89.5	5	5	1	0.925675	0.005524
92.5	92.5	0	92.5	5	5	1	0.952889	0.002219
95.5	95.5	0	95.5	4	4	1	0.970457	0.000873
98.5	98.5	0	98.5	1	1	1	0.9816	0.000339
101.5	101.5	0	101.5	1	1	1	0.988589	0.00013
107.5	107.5	0	107.5	1	1	1	0.995643	1.9E-05
110.5	110.5	0	110.5	1	1	1	0.997313	7.22E-06
149.5	149.5	0	149.5	1	1	1	0.999995	2.43E-11
161.5	161.5	0	161.5	1	1	1	0.999999	5.02E-13
164.5	164.5	0	164.5	1	1	1	1	1.9E-13
170.5	170.5	0	170.5	1	1	1	1	2.74E-14
173.5	173.5	0	173.5	1	1	1	1	1.04E-14
	More	0	More	0	0	#DIV/0!	6.49E-06	#DIV/0!

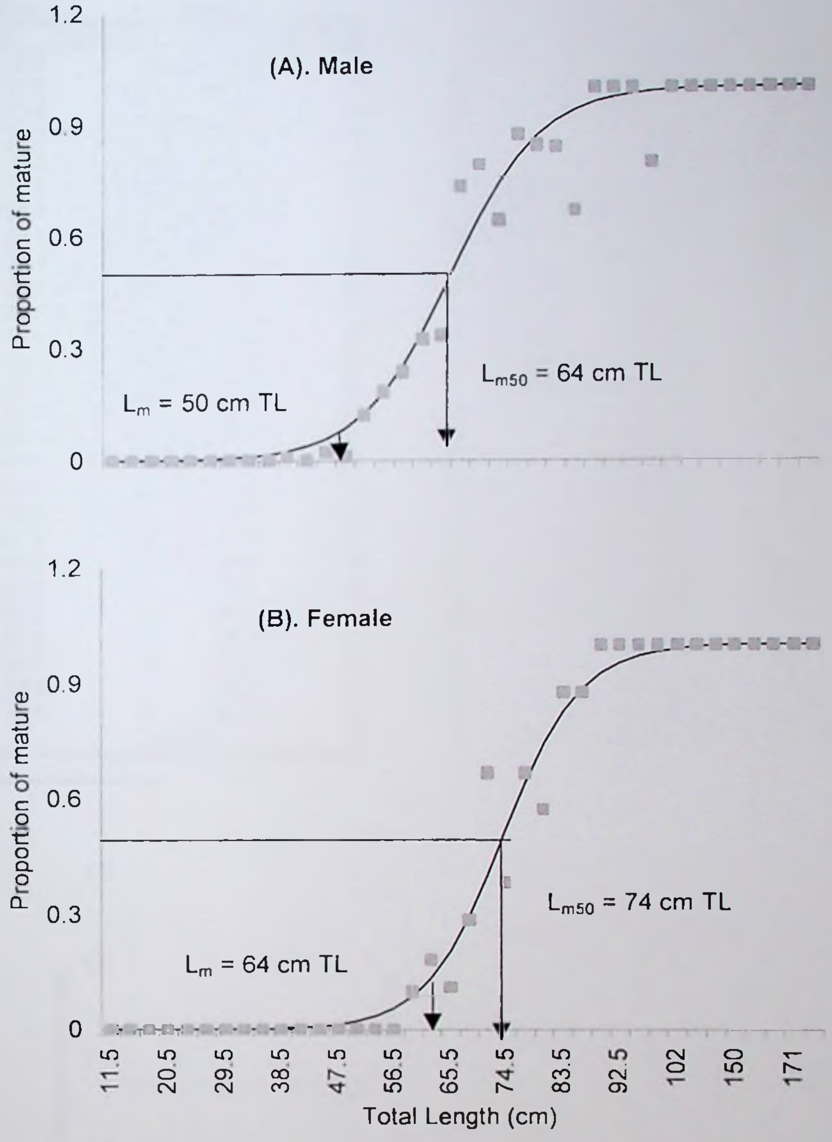


Fig. 27 . Maturity of male (A) and female (B) *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria, January 1999 to December 2000. (L_m = size at first maturity, L_{m50} = size at 50% maturity)

Table 25. Regression results for male *Oreochromis niloticus* caught in bottom trawls in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Males	M=3	a	b	ssq	L50
		15.9	0.6	0.6	**27.1**

	Immature Bin	Immature Frequency	Mature Bin	Mature Frequency	Total	obs.	Pred.	ssq
9.5	9.5	1	9.5	0	1	0	3.33757E-05	1.11394E-09
11.5	11.5	26	11.5	0	26	0	0.000107324	1.15184E-08
13.5	13.5	113	13.5	0	113	0	0.000345058	1.19065E-07
15.5	15.5	85	15.5	0	85	0	0.001108812	1.22946E-06
17.5	17.5	39	17.5	0	39	0	0.003557052	1.26526E-05
19.5	19.5	38	19.5	1	39	0.025641	0.011349551	0.000204246
21.5	21.5	42	21.5	1	43	0.023256	0.035603264	0.00015246
23.5	23.5	54	23.5	5	59	0.084746	0.106123103	0.000456991
25.5	25.5	42	25.5	18	60	0.3	0.276303712	0.000561514
27.5	27.5	31	27.5	34	65	0.523077	0.551127181	0.000786817
29.5	29.5	7	29.5	37	44	0.840909	0.79791653	0.00184836
31.5	31.5	2	31.5	22	24	0.916667	0.926995005	0.000106675
33.5	33.5	2	33.5	22	24	0.916667	0.976096055	0.003531852
35.5	35.5	2	35.5	35	37	0.945946	0.992442395	0.00216192
37.5	37.5	0	37.5	33	33	1	0.997637599	5.58094E-06
39.5	39.5	0	39.5	61	61	1	0.999264195	5.41409E-07
41.5	41.5	0	41.5	57	57	1	0.999771079	5.24047E-08
43.5	43.5	0	43.5	59	59	1	0.999928804	5.06887E-09
45.5	45.5	0	45.5	73	73	1	0.99997786	4.90182E-10
47.5	47.5	0	47.5	73	73	1	0.999993115	4.73995E-11
49.5	49.5	0	49.5	70	70	1	0.999997859	4.58334E-12
51.5	51.5	0	51.5	68	68	1	0.999999334	4.43187E-13
53.5	53.5	0	53.5	48	48	1	0.999999793	4.2854E-14
55.5	55.5	0	55.5	45	45	1	0.999999936	4.14376E-15
57.5	57.5	0	57.5	32	32	1	0.99999998	4.00681E-16
59.5	59.5	0	59.5	23	23	1	0.999999994	3.87438E-17
61.5	61.5	0	61.5	10	10	1	0.999999998	3.74633E-18
	More	1	More	3	4	0.75	1.29951E-07	0.562499805

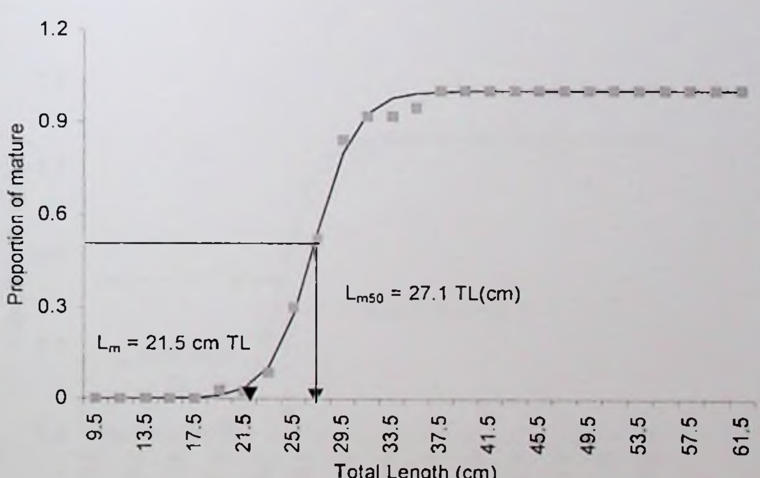


Fig.28. Maturity of male *Oreochromis niloticus* caught during bottom trawl surveys in Uganda sector of Lake Victoria between January 1999 and December 2000. (L_m = size at first maturity, L_{m50} = size at 50% maturity)

Table 26. Regression results for female *Oreochromis niloticus* caught in bottom trawls in the Uganda sector of Lake Victoria between January 1999 and December 2000.

	Female F=3								
	Immature		Mature				F=3		
	Bin	*Frequency*	*Bin*	*Frequency*	Total	a	b	ssq	L50
9.5	9.5	1	9.5	0	1	16.1	0.6	0.1	**26.8**
11.5	11.5	6	11.5	0	6	Obser.	Pred.	ssq.	
13.5	13.5	13	13.5	0	13	0.000000	0.000031	0.000000	
15.5	15.5	15	15.5	0	15	0.000000	0.000103	0.000000	
17.5	17.5	7	17.5	0	7	0.000000	0.000343	0.000000	
19.5	19.5	1	19.5	0	1	0.000000	0.001143	0.000001	
21.5	21.5	10	21.5	2	12	0.000000	0.003794	0.000014	
23.5	23.5	18	23.5	1	19	0.000000	0.012520	0.000157	
25.5	25.5	22	25.5	11	33	0.166667	0.040502	0.015917	
27.5	27.5	16	27.5	24	40	0.052632	0.123216	0.004982	
29.5	29.5	4	29.5	23	27	0.333333	0.318737	0.000213	
31.5	31.5	2	31.5	33	35	0.600000	0.609011	0.000081	
33.5	33.5	0	33.5	28	28	0.851852	0.838335	0.000183	
35.5	35.5	1	35.5	32	33	0.942857	0.945248	0.000006	
37.5	37.5	0	37.5	42	42	1.000000	0.982899	0.000292	
39.5	39.5	0	39.5	39	39	0.969697	0.994801	0.000630	
41.5	41.5	0	41.5	43	43	1.000000	0.998433	0.000002	
43.5	43.5	0	43.5	44	44	1.000000	0.999529	0.000000	
45.5	45.5	0	45.5	30	30	1.000000	0.999858	0.000000	
47.5	47.5	0	47.5	25	25	1.000000	0.999957	0.000000	
49.5	49.5	0	49.5	18	18	1.000000	0.999987	0.000000	
51.5	51.5	0	51.5	11	11	1.000000	0.999996	0.000000	
53.5	53.5	0	53.5	8	8	1.000000	0.999999	0.000000	
55.5	55.5	1	55.5	5	6	1.000000	1.000000	0.000000	
57.5	57.5	0	57.5	5	5	1.000000	1.000000	0.000000	
59.5	59.5	0	59.5	3	3	0.833333	1.000000	0.027778	
61.5	61.5	0	61.5	2	2	1.000000	1.000000	0.000000	
	More	0	More	0	0	1.000000	1.000000	0.000000	
						1.000000	1.000000	0.000000	
						#DIV/0!	0.000000	#DIV/0!	

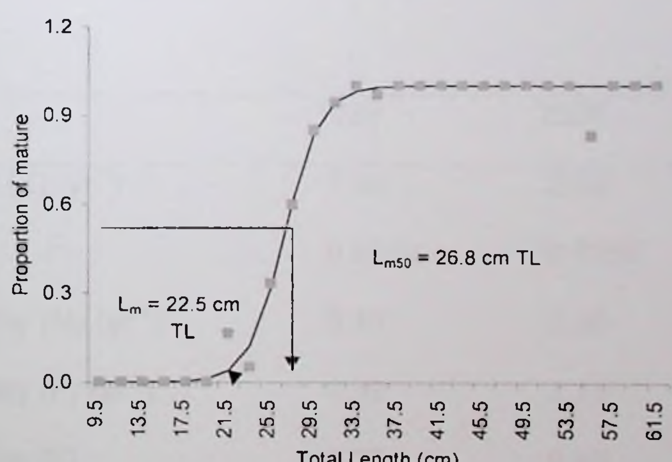


Fig. 29. Maturity of female *Oreochromis niloticus* caught during bottom trawl surveys in Uganda sector of Lake Victoria between January 1999 and December 2000. (L_m = size at first maturity, L_{m50} = size at 50% maturity)

4.5.3. **Mortality rates**

4.5.3.1. *L. niloticus*

The total mortality rate (Z) during 1999-2000 was estimated at 1.91 yr^{-1} (95% Confidence limits 2.39 to1.44, r^2 = 0.8411) using the length-converted catch curve (Table 27, Fig. 30). Natural mortality (M) was estimated at 0.42 yr^{-1}, fishing mortality (F) was computed (F = Z-M) as 1.49 yr^{-1} and exploitation rate (E) computed (E = F/Z) as 0.78 (Table 27).

Table 27. Mortality estimates for *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000

(i) Annually

	1999	2000	1999/2000
Total mortality (Z) (yr^{-1})	1.80	2.63	1.91
r^2	0.5309	0.6257	0.8411
Natural mortality (M) (yr^{-1})	0.41	0.40	0.42
Fishing mortality (F) (yr^{-1})	1.39	2.23	1.49
Exploitation rate (E)	0.77	0.85	0.78

(ii) For Zones in 1999/2000.

	1999/2000		
	Zone I	Zone II	Zone III
Total mortality (Z) (yr^{-1})	3.33	1.96	2.59
r^2	0.9418	0.9343	0.8685
Natural mortality (M) (yr^{-1})	0.40	0.29	0.28
Fishing mortality (F) (yr^{-1})	2.94	1.67	2.31
Exploitation rate (E)	0.88	0.85	0.89

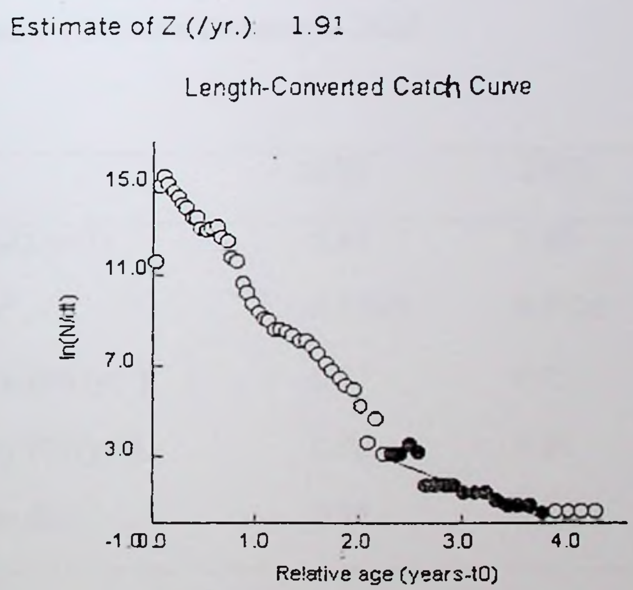


Fig. 30. Total mortality (Z) estimate of *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

4.5.3.2. *Oreochromis niloticus*

The total mortality rate (Z) during 1999-2000 was estimated at 1.65 yr^{-1} (95% Confidence limits 1.91 to 1.39 , r^2 = 0.9027) using the length-converted catch curve (Table 28, Fig. 31). Natural mortality (M) was estimated at 0.72 yr^{-1}. Fishing mortality (F) was computed (F = Z-M) as 0.95 yr^{-1} and exploitation rate (E) computed (E = F/Z) as 0.57 (Table 28).

Table 28. Mortality estimates for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000

	1999	2000	1999/2000
Total mortality (Z) (yr^{-1})	1.49	1.62	1.65
r^2	0.9749	0.8726	0.9027
Natural mortality (M) (yr^{-1})	0.67	0.72	0.72
Fishing mortality (F) (yr^{-1})	0.82	0.90	0.95
Exploitation rate (E)	0.77	0.79	0.57

Estimate of Z (/yr.): 1.65

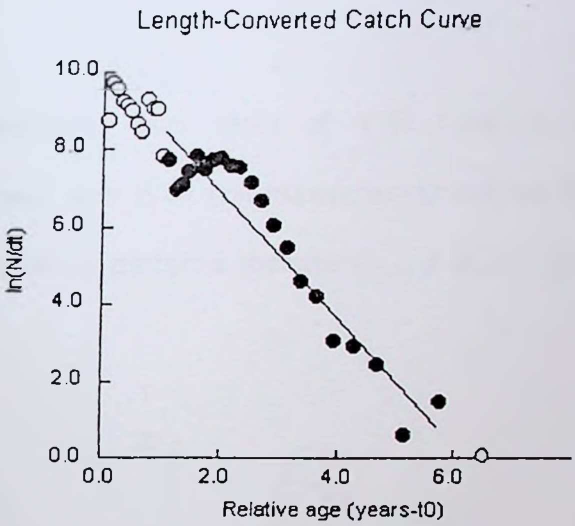


Fig. 31. Total mortality estimates for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 to December 2000.

4.5.4. Recruitment patterns

4.5.4.1. *Lates niloticus*

Two groups of recruitment pulses were observed during 1999-2000 (Table 26. Fig. 32): one from January to May with March being the highest (18.03%), the other had August as the highest recruitment (11.49%). Comparatively the March recruitment was stronger but of short duration (Fig. 32). In December there was no recruitment.

Exploitation patterns and plots of Y'/R (relative yield-per-recruit) vs E (exploitation rate) and B'/R (biomass-per-recruit) vs E are also given in Fig. 33. The exploitation patterns include E_{max} = 0.390, $E_{0.10}$ = 0.320 and $E_{0.50}$ = 0.255.

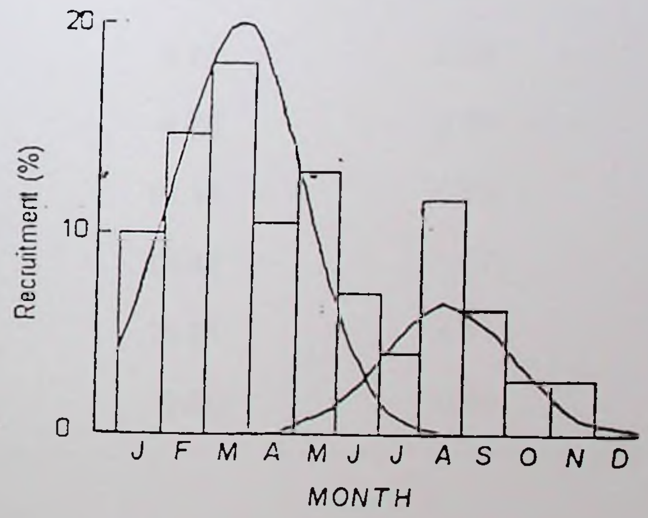


Fig. 32. Recruitment patterns for *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 to December 2000.

Table 29. Recruitment patterns for *L. niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Relative recruitment values			
Relative time	Recruitment (percentage)		
(Month)	1999	2000	1999-2000
January	3.63	4.62	9.99
February	2.71	9.27	14.79
March	6.63	15.45	18.03
April	12.23	17.20	10.30
May	7.78	17.85	12.86
June	7.35	10.85	7.04
July	4.71	3.99	4.08
August	4.78	9.56	11.49
September	16.18	5.52	6.00
October	18.42	1.57	2.66
November	15.91	4.11	2.76
December	0.00	0.00	0.00

Lc/Lco:	0.050	E-max:	0.390	E-50:	0.255
M/K:	1.44	E-10:	0.320		

E	Y/R	B/R	E	Y/R	B/R
0.01	0.014	0.785	0.60	0.024	0.098
0.20	0.024	0.595	0.70	0.016	0.043
0.30	0.030	0.429	0.80	0.008	0.013
0.40	0.031	0.291	0.90	0.002	0.002
0.50	0.029	0.180	0.99	0.000	0.000

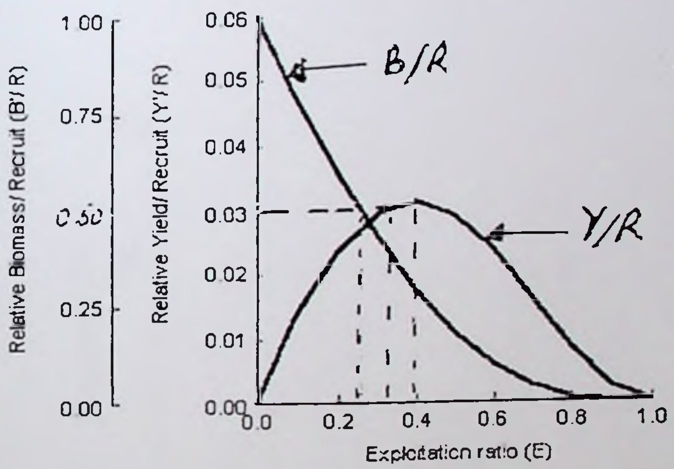


Fig. 33. Exploitation patterns and plots of yield-per-recruit for *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

4.5.4.2. *Oreochromis niloticus*

As in *L. niloticus*. two groups of recruitment pulses were observed during 1999-2000 (Table 29. Fig. 34): one from January to June with April being the highest (14.61%), the other had September as the highest recruitment (22.09%). The March recruitment was stronger (Fig. 34).

Exploitation patterns and plots of Y'/R vs E and B'/R vs E are also given in Fig. 35. The exploitation patterns include E_{max} = 0.374, $E_{0.10}$ = 0.306 and $E_{0.50}$ = 0.244.

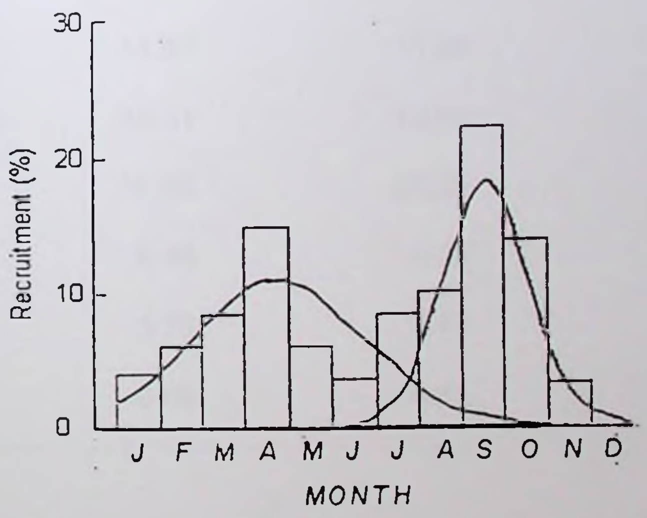


Fig. 34. Recruitment patterns for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Table 30. Recruitment patterns for *O. niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Relative recruitment values			
Relative time	Recruitment (percentage)		
(Month)	1999	2000	1999-2000
January	1.31	2.17	3.84
February	0.62	4.26	5.99
March	2.74	7.81	8.56
April	8.15	12.00	14.61
May	10.78	3.06	6.00
June	9.93	0.00	3.63
July	14.97	11.38	8.33
August	23.31	10.55	9.91
September	15.92	26.25	22.09
October	8.48	18.75	13.80
November	3.73	3.79	3.34
December	0.00	0.00	0.00

Lc/Loo: 0.050	E-max: 0.374	E-50: 0.244
M/K: 1.8	E-10: 0.306	

E	Y/R	B/R	E	Y/R	B/R
0.01	0.010	0.774	0.60	0.015	0.087
0.20	0.017	0.577	0.70	0.010	0.038
0.30	0.021	0.409	0.80	0.005	0.011
0.40	0.021	0.272	0.90	0.002	0.001
0.50	0.019	0.165	0.99	0.000	0.000

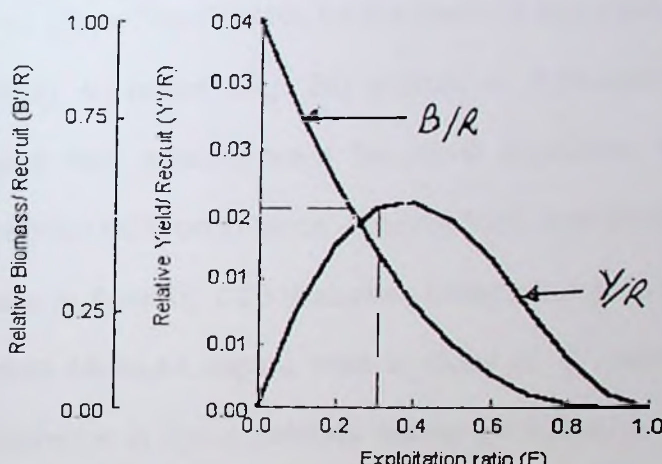


Fig. 35. Exploitation patterns and plots of yield-per-recruit for *Oreochromis niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria. January 1999 to December 2000.

4.6. **Food of *Lates niloticus***

On the basis of 3612 stomachs from the fish specimens caught during the period January 1999 to September 2000, the items ingested by *L. niloticus* included *Caridina nilotica, Chaoborus* spp., *Chironomus* spp., *Clarias gariepinus*, detritus, *Ephemeroptera* spp., fish remains, *Haplochromis* spp., *Lates niloticus* juveniles, *Mastacembelus* sp., *Odonata* spp., *Oreochromis* spp., *Povilla* spp., *Protopterus* sp., *Rastrineobola argentea*, snails and *Synodontis* spp.

The importance of these "food" items, on the basis of occurrence, varied with the habitats (grids) surveyed (Fig. 36) (details in Appendices 13 & 14). Whereas fish and fish remains were the most important "food" items – constituting more than 60% occurrence – during 1999 and 2000 in B04 (Bussi and Entebbe Bays in Zone II), C03 (Kasakah-Mweza-Lunguru area in Zone I) and D03 (Kasakah-Mweza-Lunguru area in Zone I), *C. nilotica* constituted 12.1-23.0% occurrence in these habitats during the same period. However. *C. nilotica* was generally the most important "food" item in all habitats, constituting 49.7% and 45.6% occurrence during 1999 and 2000, respectively.

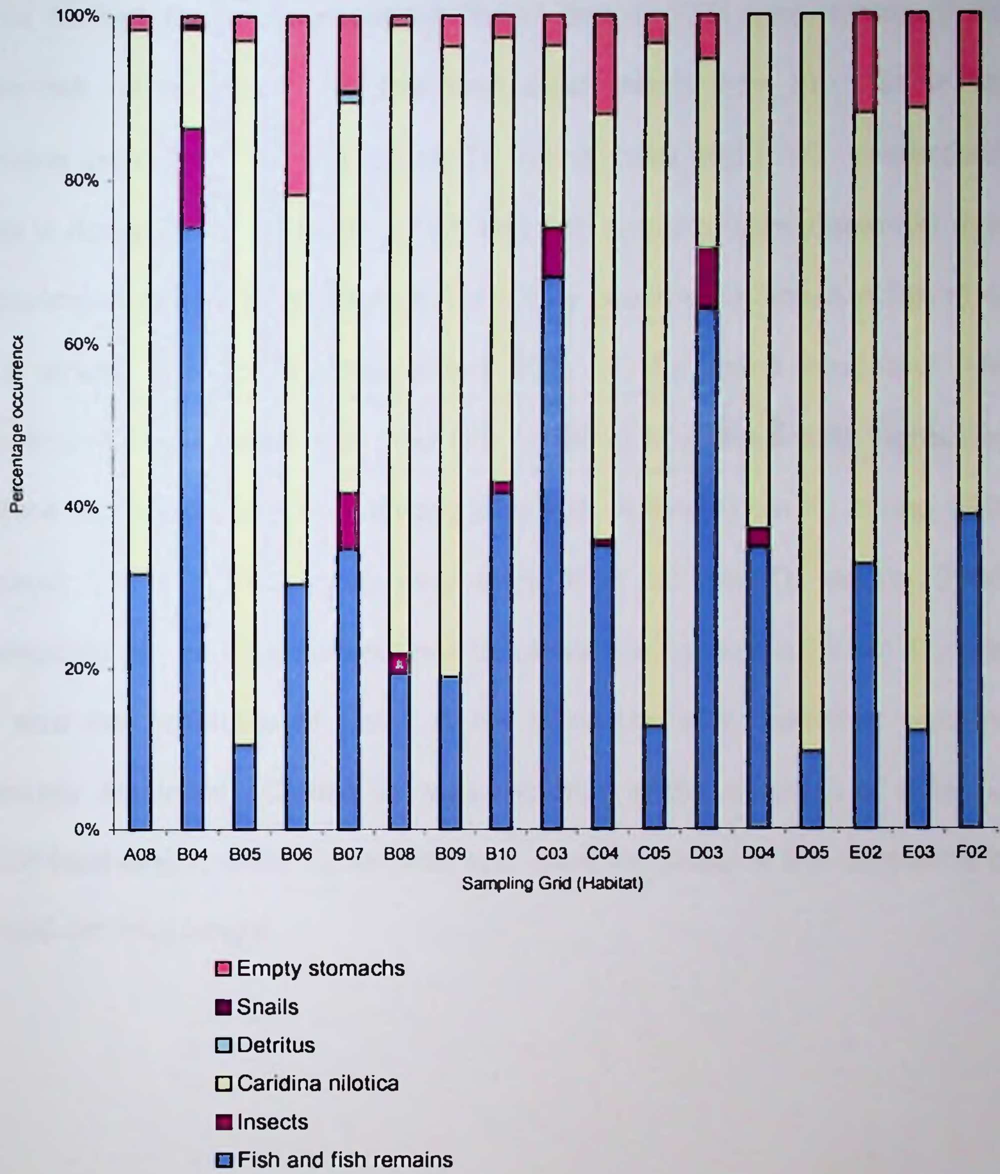


Figure 36. Variation in items ingested by *Lates niloticus* caught in different grids during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
[Fish and fish remains: *Haplochromis* spp, *Lates* sp, *Mastacembelus* sp, *Oreochromis* sp, Clarias sp, *Protopterus* sp, *Rastrineobola* sp, *Synodontis* sp, fish remains.
[Insects: *Chaoborus, Chironomus,* Ephemeroptera, *Povilla, Odonata]*

Fig. 37 illustrates items ingested by various sizes of *L. niloticus*. *Caridina niloticus* formed the most important "food" item (>40% occurrence) of the juvenile fish up to 40 cm TL; this item disappeared from the diet of fish specimens larger than 90 and 70 cm TL during 1999 and 2000, respectively (details in Appendices 15 & 16). Fish and fish remains were observed from fish specimens of total length from 6.2 cm; they became dominant in fish of 40 cm TL where they contributed about 50% of the items ingested. The occurrence of these items (fish and fish remains) increased with increasing size of the fish specimens, contributing over 90% in fish 60 cm TL during 1999 and about 100% in fish measuring more than 90 cm TL during 2000. *Rastrineobola* sp. and haplochromines dominated in fish up to 70 cm TL after which size the presence of *Lates* in the stomachs of *L. niloticus* became increasingly dominant. *Clarias* sp. was recorded in the stomach of a fish of 100+ cm total length while *Synodontis* spp. were recorded in the stomachs of fish 70-80 cm total length.

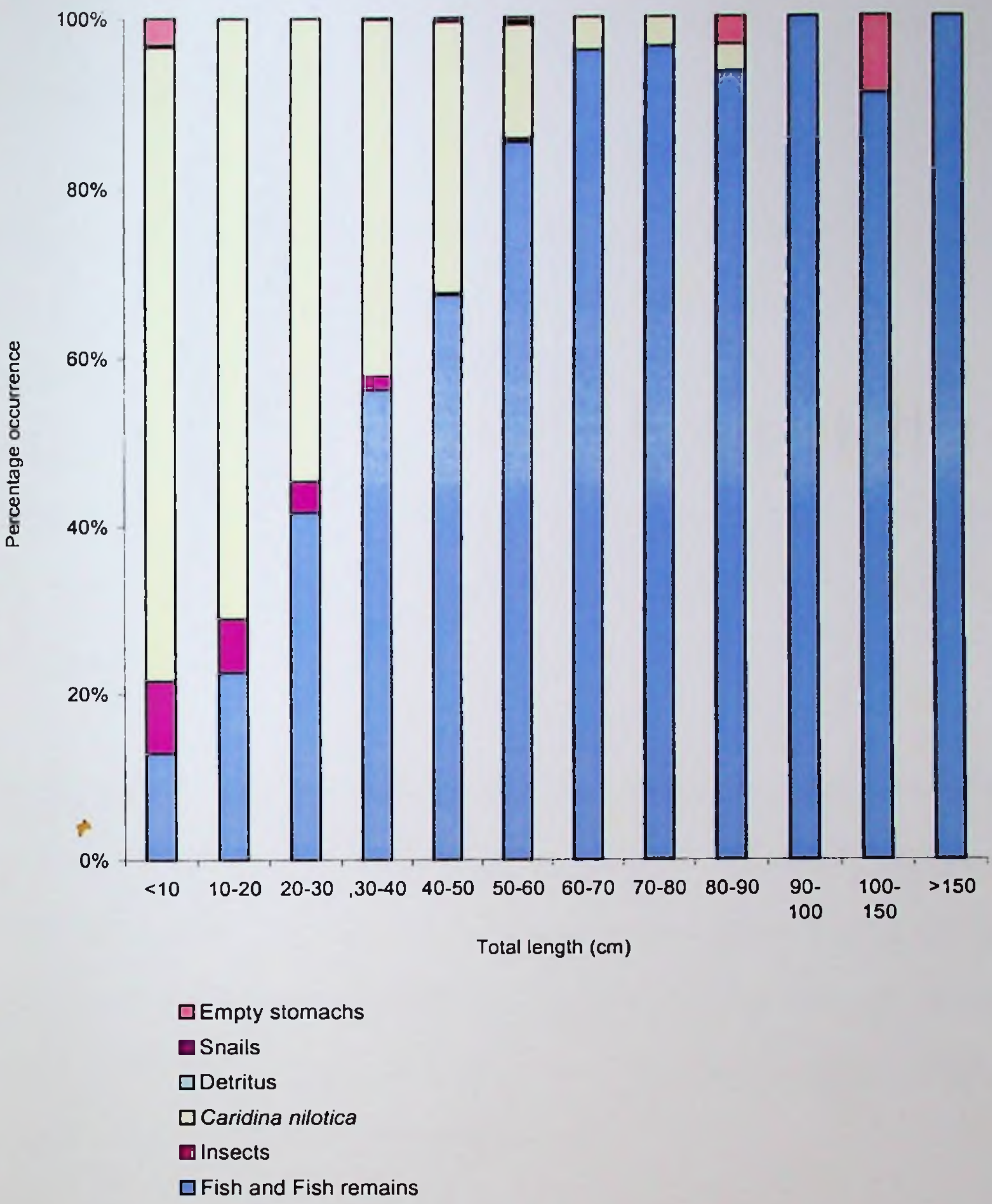


Figure 37. Variation in items ingested by different sizes of *Lates niloticus* caught during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

[Fish and fish remains: *Haplochromis* spp, *Lates* sp, *Mastacembelus* sp, *Oreochromis* sp, Clarias sp, *Protopterus* sp, *Rastrineobola* sp, *Synodontis* sp, fish remains.

[Insects: *Chaoborus, Chironomus,* Ephemeroptera, *Povilla, Odonata]*

4.7. Environmental parameters

4.7.1. Temperature

Temperature profiles for Napoleon Gulf (20 m maximum depth) during the months of January, March, July and August 1999 are presented in Fig. 38; these months represent the four different seasons. The water temperature ranged from 28.1°C at the surface to 24°C at the bottom. In January, temperature was 27.4-26.4 °C while the temperatures recorded (depth at bottom in brackets) in March, July and August were 28.1-26.9 °C (16 m), 25-24 °C (20 m) and 26-25 °C (20 m).

In Bugaia Island waters, an open deep (70 m maximum depth) station/area, the water temperatures during 1999 ranged from 26.7 °C at the surface to 24.2 °C at the bottom (Fig. 39). The temperatures recorded during the four different seasons (depth at the bottom in brackets) were 26.7-24.4 °C (66 m), 25.7-24.2 °C (64 m), 25.9-24.7 °C (68 m) and 25.2-24.4 °C (66 m) during January, March, June and August, respectively.

In Lujabwa Island waters (40 m maximum depth) in Zone I, water temperature recorded during February and March 2000 were 24.9-24.5 °C and 25.6-24.8 °C, respectively (Fig. 40). Temperatures for Nsadzi Island water during November 1999 ranged from 25.1 at the surface to 24.0 at the bottom.

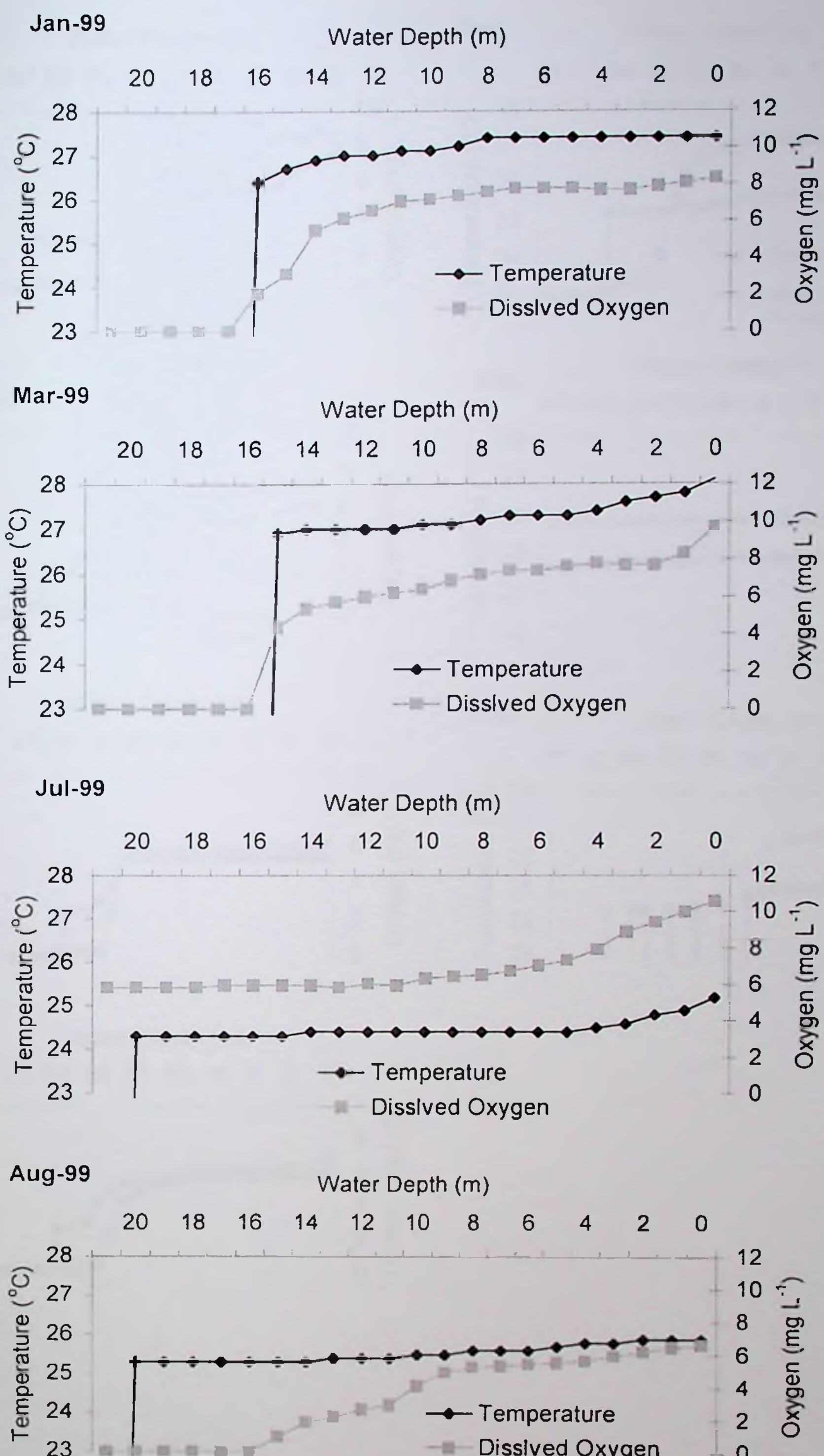


Fig. 38. Temperature and Dissolved Oxygen profiles for Napoleon Gulf in Lake Victoria (Uganda) during 1999.

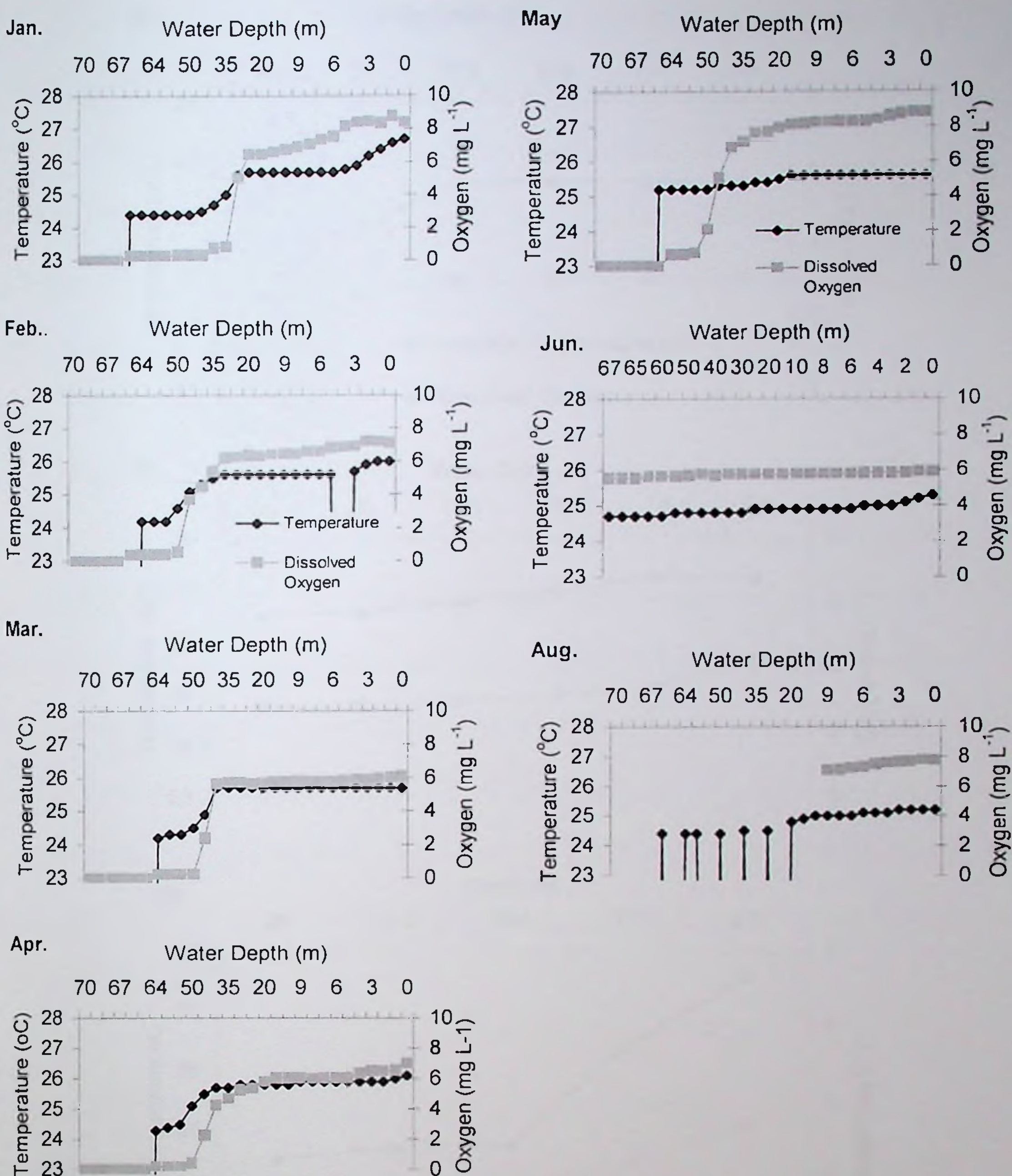


Fig. 39. Temperature and Dissolved Oxygen profiles for Bugaia Island waters of Lake Victoria (Uganda) during 1999.

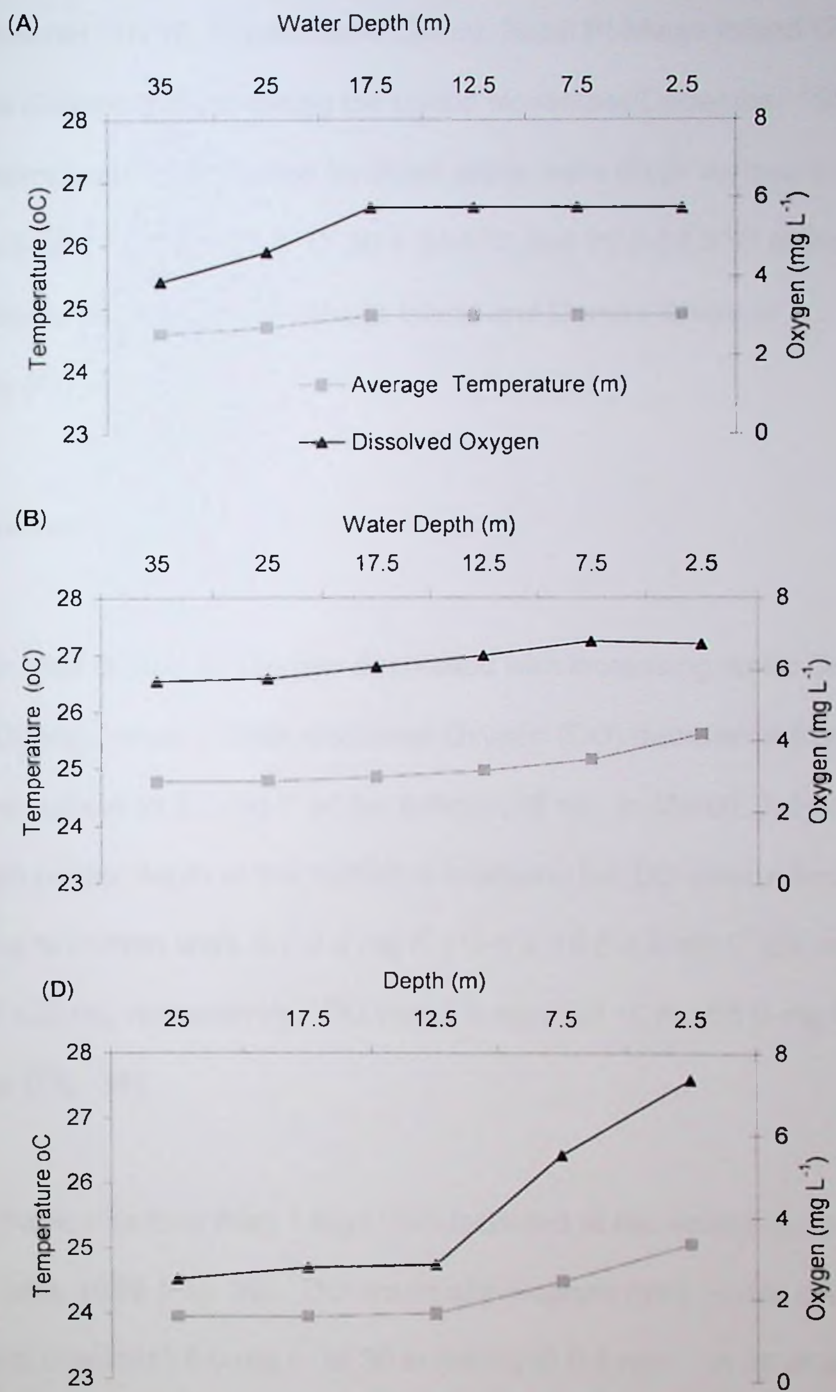


Fig. 40 . Temperature and Dissolved Oxygen distribution profiles for (A) Lujabwa Island in February 2000, (B) Lujabwa Island in March 2000 and (D) Nsadzi Island in November 1999.

Figure 41 shows the water temperature profiles for (water depth in brackets) Buvuma Channel (15 m), Sigulu Island (26 m), Busiji Pt-Mvuja Island (26 m) and Damba Channel (25 m) during the period November/December 1999. The water temperatures recorded for these areas were (from surface to bottom) 29.8-26.1 °C, 25.5-25.0 °C, 26.1-24.5 °C and 25.2-23.9 °C in Buvuma Channel, Sigulu Island, Busiji Pt-Mvuja Island and Damba Channel, respectively (Fig. 41)

4.7.2. Dissolved Oxygen

In Napoleon Gulf dissolved Oxygen decreased with increasing water depth (Fig. 38). During January 1999, dissolved Oxygen (DO) decreased from 8.3 mg l^{-1} at the surface to 2.1 mg l^{-1} at the bottom (16 m). In March, July and August 1999 (water depth at the bottom in brackets) the DO values recorded from surface to bottom were 9.7-4.4 mg l^{-1} (15 m), 10.6-5.8 mg l^{-1} (20 m) and 6.6-0 mg l^{-1} (20 m), respectively. DO was 2.9 mg l^{-1} at 11 m and 0 mg l^{-1} at 18 m in August (Fig. 38).

In Bugaia, there was less than 1 mg l^{-1} DO recorded at the bottom during January to May 1999 (Fig. 39). DO drastically dropped from (water depth at the bottom in brackets) 5.0 mg l^{-1} at 30 m (66 m) to 0.9 mg l^{-1} at 35 m during January and from 5.7 mg l^{-1} at 40 m (65 m) to 0.4 mg l^{-1} at 45 m during March (Fig. 39). During June and August the DO values recorded from surface to the bottom (depth at the bottom in brackets) were 6.0-5.6 mg l^{-1} (68 m) and 7.7-3.7 mg l^{-1} mg l^{-1} (66 m).

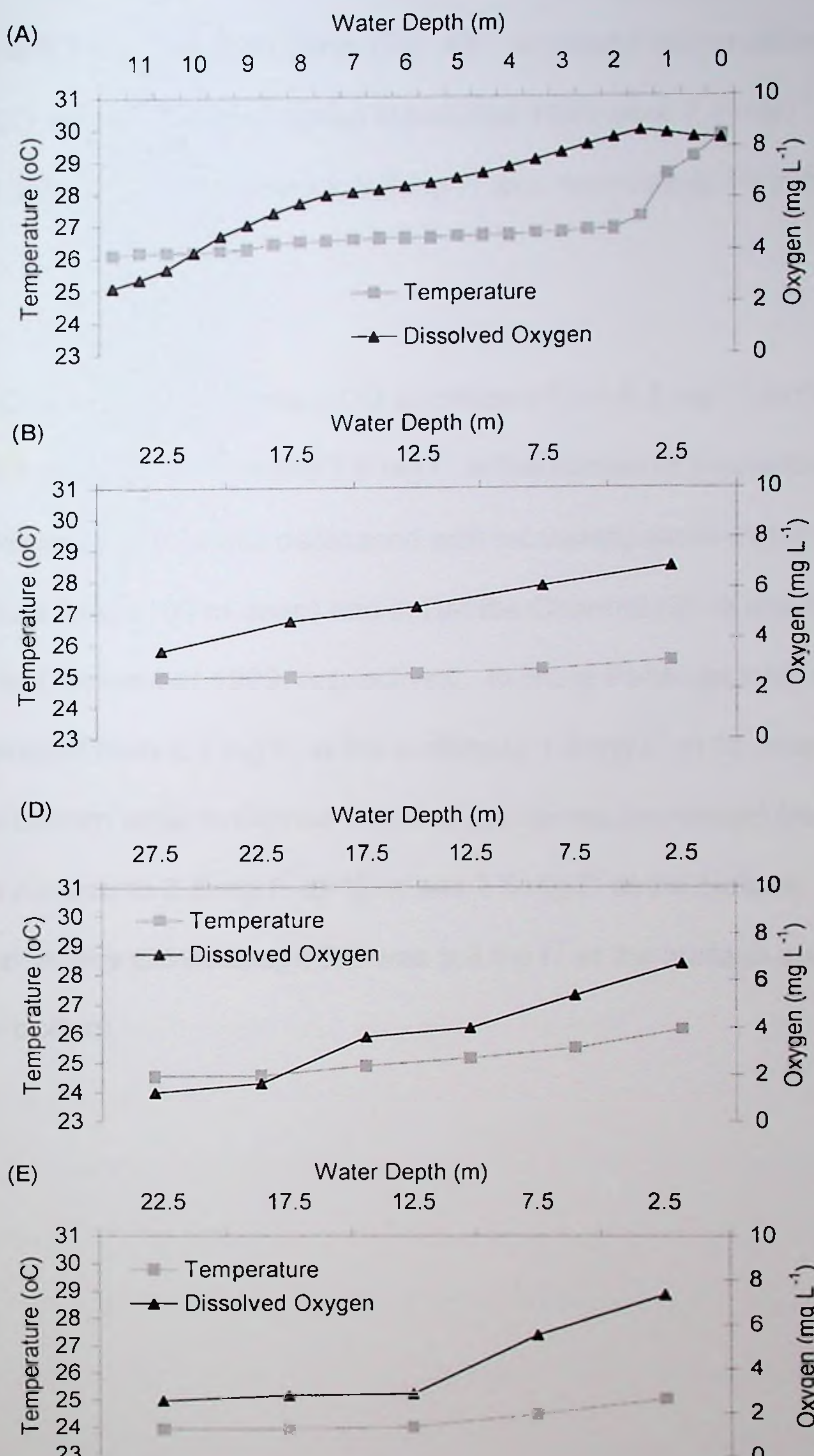


Fig. 41 . Temperature and Dissolved oxygen distribution profiles for (A) Buvuma Channel, (B) Sigulu Island (D) Busiji Pt-Mvuja Island and (E) Damba Channel during November/December 1999.

DO in Lujabwa Island (40 m deep) waters decreased from 5.7 mg l^{-1} at the surface to 3.9 mg l^{-1} at the bottom during February 1999 and from 6.7 mg l^{-1} at the surface to 5.7 mg l^{-1} at the bottom (Fig. 40). In Nsadzi Island waters (30 m deep), the DO values recorded during November 1999 were 7.4 mg l^{-1} at the surface and 2.5 mg l^{-1} at the bottom; 2.8 mg l^{-1} was recorded at 15 m (Fig. 40).

In Buvuma Channel (11.5 m deep), DO decreased from 8.4 mg l^{-1} at the surface to 3.3 mg l^{-1} at 10.5 m and 2.6 mg l^{-1} at the bottom in December 1999 (Fig. 41). Similarly, DO values decreased with increasing water depth in both Busiji Pt-Mvuja Island (30 m deep) and in Damba Channel (25 m deep) during December and November 1999, respectively. In Busiji Pt-Mvuja Island, DO values decreased from 6.7 mg l^{-1} at the surface to 1.6 mg l^{-1} at 25 m and 1.2 mg l^{-1} at the bottom while in Damba Channel the values decreased from 7.4 mg l^{-1} at the surface to 2.8 mg l^{-1} at 15 m and 2.5 mg l^{-1} at the bottom. In Sigulu Island waters (26 m deep), DO was 6.9 mg l^{-1} at the surface and 3.5 mg l^{-1} at the bottom.

CHAPTER 5

5.0. DISCUSSION

5.1. Fish species composition and distribution.

During the lakewide bottom trawl survey of 1969/71 (Kudhongania & Cordone, 1974), 24 fish species in 21 genera were encountered in addition to the abundant haplochromine cichlids. There was a well-defined trend in the number of species by depth with maximum species diversification in the shallows. The catches were dominated by the *Haplochromis* complex (83% by weight) followed by *B. docmak* (4.2%), *Clarias mossambicus* (now *Clarias gariepinus*) (4.1%), *O. esculentus* (3.8%), *P. aethiopicus* (2.8%), *O. niloticus* (0.5%) and *S. victoriae* (0.4%).

Bottom trawling in the northern portion of the Uganda waters of Lake Victoria from 1981 to 1985 (Okaronon *et al.*, 1985; Okaronon & Kamanyi, 1986) recorded all but two of the non- cichlid species (*Gnathonemus longibarbis* and *Brycinus* spp) found in the 1969/71 surveys. Haplochromines declined from 91.4% of the catch by weight in 1981 to almost zero in 1985, while the contribution of *L. niloticus* increased from 5% to 96 % during the same period. During the survey from May 1993 to October 1997 – covering selected transects in the Uganda portion of Lake Victoria - *Lates niloticus* contributed 96.5% of the catch by weight (Okaronon *et al.*, 1999). Fish diversity and abundance decreased with increasing water depth. In the survey of 1997/1998, four fish taxa recorded during the 1993/1997 surveys (*Barbus altianalis, Brycinus* spp., *O. variabilis* and *X. eupogon*) were not caught in, suggesting a further decline in fish species diversity (Okaronon *et al.*, 1999). More fish were recorded in waters less than 30 m deep during 1997/1998 (93% of total weight)(Okaronon *et al.*, 1999) than during 1993/1994 (70%) (Okaronon, 1994) and during this study (76%).

During the bottom trawl surveys of January 1999 to December 2000, 17 fish taxa (belonging to 14 genera) were encountered in the Uganda portion of Lake Victoria. Two additional fish species, *Aethiomastacembelus frenatus* and *Tilapia rendalli*, were recorded in 1999; *A. frenatus* was encountered for the first time since the 1969/71 bottom trawl surveys while *T. rendalli* was encountered for the first time ever. The appearance of these, seemingly rare, species during this period (1999) may partly be due to high frequency of sampling the areas compared to period prior to 1969/71 and pre-1999/2000. For the introduced *T. rendalli*, however, this species is reported to prefer shallow areas with a good aquatic weed cover (Witte & van Densen, 1995); thus in 1999, during the heavy rains, the species may have found itself in the area it was caught. Similarly, *A. frenatus* is reported to be found in marginal swamps (Witte & van Densen, 1995), thus as a result of the heavy rains of 1999, the species found itself in the area it was caught. There has, therefore, been a decline in the species composition in the lake since the survey of 1969/1971. This decline may have been caused by competition for space and food with the introduced species, predation by the Nile perch and changes in the aquatic environment, resulting from accumulation of nutrients from increased activities in the catchment areas.

The highest catches of *L. niloticus* in bottom trawls during 1999/2000 were obtained in Zone I, and Zone III had the lowest concentrations of fish. This trend was also reported during the period 1993-1998 (Okaronon, 1994; Okaronon *et al.*, 1999). The explanation may partly be due to the high fishing pressure in Zone III as indicated by a high mortality rate (Z) of 1.73 compared to Z=1.47 in Zone I during 1993-1998 (Okaronon *et al.*, 1999). Whereas the stock densities have been reported to decrease with increasing water depth (Kudhongania & Cordone, 1974; Okaronon et al., 1985; Okaronon, 1994), the peak catches of *L. niloticus* in Zone I were obtained in the 20-30 m water depth area during the trawl surveys in 1999/2000. Zone I in the Uganda portion of Lake Victoria is an open water area adjacent to the open waters of the Tanzania portion of the lake. This area is, most of the year, exposed to strong winds, mainly from Tanzania. The turbulence caused by these winds restrict the fishing activities in this area to immediate shoreline waters. Thus the open deep waters of this zone are not very often subjected to intensive fishing pressure.

Length frequency data for *L. niloticus* suggest that all size groups were found in all areas surveyed during bottom trawling. The preponderance of small fish in the deep waters may be a tactic to avoid predation by their larger con-specifics. Alternatively, the small fish in these deep waters may be here to exploit the abundant food resources, especially *Caridina nilotica*, known to exist in this region where Oxygen levels are depleted and thus making it inaccessible to larger fish that have lower tolerance to low Oxygen levels. Juveniles of *L. niloticus* of less than 6 cm TL were found in all areas surveyed. This may suggest that breeding of *L. niloticus* takes place throughout the lake. Witte and van Densen (1995) reported that in Lake Victoria, juvenile Nile perch of less than 10 cm TL had been caught in waters up to 60 m deep but the highest densities were found in the shallow littoral zones. In Lake Tanganyika, the young of *Lates* occupy the littoral *Ceratophyllum* weed beds until they reach 18-20 cm TL when they then leave the weed beds and spread out into deep water (Coulter, 1965).

O. niloticus, during the bottom trawl surveys in 1999/2000, were restricted to water <20 m deep; this was also observed in other previous surveys in the Uganda portion of Lake Victoria (Kudhongania and Cordone, 1974; Okaronon et al., 1985; Okaronon, 1994; Okaronon *et al.*, 1999). During the 1999/2000 surveys, the bulk of (93% by weight, 40% by numbers) *O. niloticus* were mature (>22 cm TL). This is partly due to the sampling technique that only covered waters 4-60 m deep leaving the waters <4 m deep, a potential area for the small, young fish. During the gill net surveys in the shallow inshore areas, about 70% (by weight) and 86% (by numbers) of *O. niloticus* were immature (<22 cm TL).

In the monofilament gill net surveys, *L. niloticus* dominated the catches in the open deep water while *O. niloticus* dominated in the shallow inshore areas. During the multi-mesh monofilament gill net surveys in the deep offshore waters of the Uganda portion of Lake Victoria, *L. niloticus* dominated the catches, composing 93.2% (by weight), followed by *O. niloticus* with 3.5%. In Bunjako Bay-Buninga island waters (10 m maximum depth), nets set at the surface (0-5 m) retained 99.3% (by weight) of the fish compared to the fleet set at the bottom (5-10 m) which retained less than 1% of the catch. Similar observations were made in Buvuma channel-Lingira Island (17 m maximum depth) where all the catch was obtained from the nets set at 0-11 m while the nets set at the bottom (12-17 m) did not retain any fish. On the contrary, in the deeper waters of – maximum depth in brackets – Damba Channel-Mbazi Hills (24 m) in Zone II, Nsadzi-Jana Islands (44 m) in Zone II and Mu Island (23 m) in Zone II, 81.6% of the fish (by weight) were retained by the nets set at the bottom; the nets set at the surface (0-5 m) retained 6.4% of the fish while some of the nets set in mid-water did not retain any fish. However, the survey results from Sigulu Island and Busiji Pt-Mvuja Island – both 26 m maximum depth and in Zone III – differed. In Busiji Pt-Mvuja Island, 83% of the fish (by weight) was retained by nets set at the surface (0-5 m) while in Sigulu Island 55.6% and 40.8% of the fish were retained by the nets set at the surface (0-5 m) and the bottom (21-26 m), respectively. The nets set at the bottom (21-26 m) in Busiji Pt-Mvuja Island did not retain any fish. The above observations could be linked to the levels of dissolved Oxygen at the time where <3 mg l^{-1} of dissolved Oxygen was recorded at the bottom waters in both Bunjako Bay-Buninga Island and Buvuma Channel-Lingira Island while

>3 mg l^{-1} dissolved Oxygen was recorded at the bottom waters in Damba Channel-Mbazi Hills, Nsadzi-Jana Islands and Mu Island. In Sigulu, 3.5 mg l^{-1} was recorded at the bottom waters compared to 1.2 mg l^{-1} in Busiji Pt-Mvuja Island. *L. niloticus* has a relatively high Oxygen demand, requiring waters with at least 3 mg l^{-1} of dissolved Oxygen (Wannink, 1988; Mugidde, pers. Commun.) and, therefore, no catches of *L. niloticus* would expected in waters with <3 mg l^{-1} of dissolved Oxygen at the bottom.

In the inshore shallow waters, *O. niloticus* dominated the catches, contributing 44.59% by weight, followed by *L. niloticus* with 19.18%. About 50% of the catch in MacDonald Bay was *O. niloticus* compared to 21% for *L. niloticus* while the contribution of *L. niloticus* (35.37%) in the Entebbe area was very close and second to that of *O. niloticus* (36.39%).

More male than female *L. niloticus* were caught during the bottom trawl surveys in the Uganda sector of the lake in 1999 (1:5) and 2000 (1:3). The ratios of female to male ranged from 1:3 in B10 (Berkeley Bay in Zone III) to 1:10 in B09 (Luvangu-Sigulu Islands in Zone III) and 1:17 in E03 (Linga Pt-Lujabwa Island in Zone I).

Ligtvoet and Mkumbo (1990) reported that the sex ratio of *Lates* population of the Mwanza Gulf was skewed: in the smaller size classes (<80 cm TL), males greatly outnumbered the females with sex ratio M:F ranging from almost 10:1 to 7:1, but that *Lates* over 80 cm TL the proportion of males rapidly fell (1:1 at 90 cm TL, and 1:10 at 100 cm TL); specimens bigger than 120 cm TL were generally found to be females. In Lake Kyoga, a similar pattern was reported (Ogutu-Ohwayo, 1988). Hopson (1972) assumes that the numerical superiority of large females is the result of high mortality in the males. Congregation of members of one sex in particular (Hopson, 1972) and sex-inversion from males to females as observed in *Lates calcarifer* in Australia (Moore, 1979) are possible explanations as well.

5.2. Fish abundance

The experimental trawl CPUE has shown a continuous and marked decline since research trawling began in 1969. CPUE in water 4-30 m deep averaged 797 kg hr^{-1} over the 1969/1971 surveys (Kudhongania & Cordone, 1974) and markedly declined to 115 kg hr^{-1} in 1997/1998 (Okaronon *et al.*, 1999). The average catch in the 1999 survey increased to 159 kg hr^{-1}, but this slight increase was probably due to change of trawl gear with effect from November 1998 (Okaronon *et al.*, 1999). The CPUE in waters 4-30 m deep was 194 kg hr^{-1} (88 kg ha^{-1}) for *L. niloticus* and 246 kg hr^{-1} (110 kg ha^{-1}) for all fish species during the 1999/2000 surveys.

Variations in catch rates were found between regions of the lake of different depths in the Uganda portion of Lake Victoria during the 1999/2000 bottom trawl surveys. In Zone I, the peak catch of *L. niloticus* was estimated in the 20-30 m water depth area during both 1999 and 2000. The estimated abundance of *L. niloticus* in Zone II increased with increasing water depth during 1999 but during 2000, however, abundance initially increased then dropped after reaching a peak in the 10-20 m depth zone. In Zone III the catch rates increased with increasing water depth. There was a greater abundance of fish in areas between 10 m and 30 m deep and a decline in deeper waters. This may be linked to the presence of thermal and Oxygen stratification of the water column, which renders deeper water inaccessible at certain times of the year. The low densities in the shallow waters may partly be due to high fishing pressure as the areas are easily accessible (Getabu & Nyaundi, 1999).

The densities of fish varied between the different zones of the lake and between different depths within the zones in the other riparian countries of Kenya (Getabu & Nyaundi, 1999) and Tanzania (Mkumbo & Ezekiel, 1999). In the Tanzania portion of the lake, Mkumbo and Ezekiel (1999) observed that the fish catches during the survey in 1997/1998 varied with water depth but that few fish were found in waters deeper than 40 m. They attributed this to low Oxygen levels in these areas.

Oreochromis niloticus catches were only recorded in waters less than 20 m deep during 1999/2000. Fish stock densities were higher in 4-10 m deep water than in water 10-20 m deep, except in Zone II during 1999 when peak density of 2.09±1.4 t km^{-2} was recorded in 10-20 m water.

The species composition in 1969-1971 was very different from the present day and, thus, different behaviour and possible net avoidance of the species presently targeted by the trawl net may be partly responsible for the apparent decline in fish stocks (Okaronon *et al.*, 1999). Moreau (1995) observed that due to a higher swimming speed, the catchability of Nile perch in trawl nets may be lower than that of haplochromines and argues that this could result in an underestimation of the Nile perch stock. Nevertheless, an apparent seven-fold decline in stock abundance between 1971 and 1999 gives considerable cause for concern about the future of the fishery.

5.3. Fish stock biomass

After the introduction of Nile perch, total fish landings in the Tanzanian waters rose by a factor of three to four, while the standing stock of bottom-dwelling fishes in the Mwanza Gulf dropped by a factor of five to ten (from more than 250 kg ha^{-1} to less than 50 kg ha^{-1}) (Witte *et al.*, 2000). Similar observations have been made in the Ugandan part of the lake (Okaronon, 1994). For the Nyanza Gulf, where the Nile perch upsurge occurred a couple of years earlier than in other parts of the lake, Moreau (1995) found contradicting results. With the aid of ECOPATH II, a steady state model of trophic interactions in ecosystems, he estimated that between 1971 (pre-Nile perch) and 1985 (post-Nile perch) the total fish biomass in the Nyanza Gulf increased from 27 tonnes km^{-2} to 43 tonnes km^{-2} (270 kg ha^{-1} to 430 kg ha^{-1}) (Moreau, 1995). The large difference for ichthyomass in the post-Nile perch situation obtained by the two methods may have various causes: (1) inaccuracies in landing statistics (CIFA, 1988) and gaps in the knowledge of parameters that were used for ECOPATH II, some of which had to be guessed (Moreau, 1995); (2) the data used only referred to bottom-dwelling fish and neglected *Rastrineobola* *argentea*; or (3) due to a higher swimming speed, the catchability of Nile perch in trawl nets may be lower than that of haplochromines, which would result in an underestimation of the Nile perch stock in our data. Even if Moreau (1995) compensated for the latter two discrepancies, there are no indications of an increase in the ichthyomass in the Nyanza Gulf in the post-Nile perch system.

During the bottom trawl surveys in the Uganda portion of Lake Victoria in January 1999 to December 2000, 121 000 t of *L. niloticus* and 12 000 t of *O. niloticus* were estimated in the 4-40 m water depth zone. These estimates increased from 117 053 t in 1999 to 121 930 t in 2000 for *L. niloticus* and from 7316 t in 1999 to 17 070 t for *O. niloticus*. These increases may partly have been due to the El-Nino rains of 1998/1999, and the reduction in fishing pressure resulting from the ban of export of fish and fish products from the Uganda sector of Lake Victoria by the European Union during 1999. The estimated biomass of 96 kg ha^{-1} for *L. niloticus* in the 4-40 m depth area in the Uganda portion of Lake Victoria is even much lower than that for the Kenya portion given by Moreau (1995).

5.4. Fish stock population structure

During the 1999/2000 bottom trawl survey, all sizes of *L. niloticus* were caught in all areas sampled. Juvenile fish measuring <50 cm TL (size at first maturity for male *L. niloticus*) constituted 72.5 % of the catch by weight while 27.5 % was from mature fish. Accordingly, about 32 800 tonnes of the 119 491 tonnes estimated for *L. niloticus* in the 4-40 m water depth zones during the survey period 1999-2000 were mature fish. The bulk of the immature *L. niloticus* were caught in waters <20 m deep (63.36 % by numbers) and in Zone III where they (immature fish) contributed 99.02% (by numbers) during 1999-2000. The abundance of the juvenile fish of various sizes promises good future recruitment to the population while the relatively small numbers of large mature fish raises concern on the future status of the fish stocks of Lake Victoria.

Marked differences in the length frequency distributions of Nile perch were found between the zones. All zones exhibited a predominance of small sized fish with few greater than 50 cm TL. This was particularly prevalent in Zone III (Kiyindi to Uganda/Kenya border) where only 1.15% (by numbers) and 0.6% of this size group was caught in 1999 and 2000, respectively. In Zone I (Tanzania/Uganda border to Bukakata), which is more remote from large urban centres, 3.3% (by numbers) and 3.7% of *L. niloticus* were caught during 1999 and 2000, respectively. This state of the fishery of the Uganda sector of the lake was also reported for the period November 1997 and June 1999 (Okaronon *et al.* 1999). In the latter case this was considered to be indicative of heavy exploitation pressure in Zone III as supported by the high mortality (Z=1.73) compared to Z=1.47 in Zone I.

Further, in Zone I, which includes Sesse Islands and many deep-water areas, there is greater proportion of larger individuals (20-50 cm TL) (35.8% by numbers in 1999 and 72.4% in 2000) than in Zone III that is dominated by small fish (<30 cm TL). This, again, probably reflects the exploitation patterns between the regions, a point supported by the higher total mortality determined for the latter regions (Z=1.73 for Zone III, compared to Z=1.47 for Zone I during 1997/1999). Whereas this could be applicable during 1997/1999, the total mortality rates (Z) during 1999/2000 were 3.33, 1.96 and 2.59 for Zones I, II and III, respectively. The high Z value in Zone I could be a result of almost 2 years of trawling in the area by Uganda-Sino Joint Venture starting from 1999 (Mukasa, pers. Commun.).

Similar observations have been reported in the Kenya sector (Getabu & Nyaundi, 1999) and Tanzania sector (Mkumbo & Ezekiel, 1999). Nile perch in Kenyan waters is characterised by a population dominated by small fish, with few specimens bigger than 50 cm TL (Getabu & Nyaundi, 1999). This is in contrast to the situation in the 1980s when many larger fish were caught (Asila & Ogari, 1988).

5.5. Fish stock assessment and biological parameters

Acere (1985) studied the age, growth, size at first maturity and sexuality of *Lates niloticus* in the Northern portion of the Uganda waters of Lake Victoria, within the hinterland of Jinja, using data collected from commercial fish landings between 1960 and 1984. He reported that (1) Nile perch grow very fast attaining a length of 52 cm TL (mean length of 36.38 cm TL) by the end of the first year of the cohort, (2) growth rate gradually decreased between year 2 and 5 and then became almost linear up to the observed length (L_{oo}) of 190 cm TL at age 13+, (3) the maximum asymptotic mean length was 256.69 cm

TL, the growth rate (k) was 0.09 yr^{-1}, (4) *Lates niloticus* exhibited sexual dimorphism and an unequal sex ratio - the males dominated up to 120 cm TL and thereafter the females become more populous than males, and (5) the smallest sexually mature individuals observed were 53.5 cm TL male (age 1+) and 67.5 cm TL female (age 1+).

In this study the asymptotic lengths (L_∞) for *L. niloticus* and *O. niloticus* were estimated as 256 cm and 75 cm TL, respectively, while the respective growth rates for the two species were 0.29 yr^{-1} and 0.40 yr^{-1}. The size at first maturity for male and female *L. niloticus* were 50 cm and 64 cm TL, respectively, while the size at first maturity for *O. niloticus* were 21.5 cm and 22.5 cm TL for male and female, respectively. The growth rate value for *L. niloticus* in this study (0.29 yr^{-1}) is high while size at first maturity are low (50 cm TL for males and 64 cm TL for females) compared with the values obtained by Acere (1985) – growth rate of 0.09 yr^{-1} and first maturity at 53.3 cm TL for males and 67.5 cm TL for females) -. The maturity values for *L. niloticus* in this study, however, are similar to the values reported by Ogutu-Ohwayo (1990a) for Lake Kyoga.

Mortality and exploitation rates for *L. niloticus* increased from 1999 to 2000 and varied between zones. This reflected the effect of fishing intensity that was on the increase due to the increasing demand for fish, especially for the export market. The effects of the high and increased fishing intensity was especially more noticeable in Zone III, bordering Kenya; the total fishing mortality rate and, thus, exploitation rate has been high in this zone. Of recent (2000) the high total mortality (Z) in Zone I has indicated increasing fishing pressure in the area. This was, as earlier indicated, partly due to the trawling activity by the Uganda-Sino Joint Venture (Mukasa, pers. Commun.) in the area during 1999/2000. The mortality and exploitation rates for *O. niloticus* were also high; this could be a result of persistent and increased fishing pressure in its habitat which is mainly inshore and, therefore, more accessible.

During this study, recruitment in the fisheries of *L. niloticus* and *O. niloticus* occurs throughout the year but with two peak periods. The peak recruitment periods for *L. niloticus* were March and August while peak recruitment in *O. niloticus* occurred in April and September. This suggests that peak recruitment in these two species occurs during the rainy season. In the Kenya sector of the lake, Getabu & Nyaundi (1999) reported a new cohort of *O. niloticus* appearing in April.

5.6. Food and feeding habits

5.6.1. Food of *Lates niloticus*

In this study, the diet of *L. niloticus* varied with its size. *Caridina nilotica* formed the most important food item in juvenile fish up to 40 cm TL. Fish and fish remains were observed from fish specimens as young as 6.2 cm TL. The occurrence of fish in the diet of *L. niloticus* increased with increasing size of the fish specimens, becoming dominant in fish of 40 cm TL and contributing about 100% of the diet in fish of 90 cm TL. The fish taxa appearing in the items ingested by *L. niloticus* were *Rastrineobola argentea*, *Haplochromis* spp, *Lates niloticus*, *Oreochromis* sp,. *Protopterus* sp., *Clarias* sp., *Synodontis* sp., and *Mastacembelus* sp. Insects, detritus and snails also constituted the food items. *R. argentea* and haplochromines dominated the fish diet of *L. niloticus* in fish up to 70 cm TL after which the presence of *Lates* in the stomachs of *L. niloticus* became increasingly dominant. The diet of *L. niloticus* also varied with the habitats (grids); *C. nilotica* was the most important food in all habitats.

Similar studies on food and feeding of *L. niloticus* have been undertaken in the Tanzania sector (Goudswaard, 1988; Ligtvoet & Witte, 1991; Mkumbo & Ligtvoet, 1992), Kenya sector (Ogari, 1985; Okemwa, 1986; Hughes, 1986) and Uganda sector (Ogutu-Ohwayo, 1988, 1990a; Acere 1988). These scientists made similar observations on shifts in the diet of *L. niloticus*. The early reliance on *Haplochromis* had diminished considerably as this prey species had virtually disappeared from the lake. Ogutu-Ohwayo (1985) observed, in Lake Kyoga (1978-1982), that the food of the Nile perch shifted from haplochromines which were expected to form the bulk of its food to other prey, probably caused by a change in the type of prey available and that haplochromines were virtually absent from the lake, contributing less than 1% of the catch and biomass. During the period 1968-1970, Okedi (1970) observed that the *Haplochromis* were by far the chief food of Nile perch in Lake Victoria constituting 84% by weight (46% occurrence)of prey eaten; in Lake Kyoga the Haplochromis constituted 1% by weight (3% occurrence) of the prey eaten by Nile perch. During this period (1968-1970), the *Haplochromis* constituted 83% of fish biomass in Lake Victoria (Kudhongania

& Cordone, 1974) and less than 1% of fish biomass in Lake Kyoga (Ogutu-Ohwayo, 1985). There had been a corresponding increase in the appearance of *Rastrineobola argentea* in the diet and a very rapid growth in the percentage of fish feeding on *Caridina nilotica*. The young *L. niloticus* utilise *Caridina nilotica* as a major food item.

Acere (1985) reported that during the early part of the first year Nile perch fed on, among other things, prawns (*Caridina*), fish fry and small gastropods and bivalves, and later changed to prey predominantly on haplochromine cichlids and *Rastrineobola* in proportion to their abundance. During the 1981-1985 bottom trawl survey in the Northern portion of the Uganda waters of Lake Victoria, Nile perch extended the range of its major food items to include juveniles of its own and those of *O. niloticus* (Acere, 1988). The predominance of the food item was proportional to its abundance in the habitat and *Caridina* occurred in the stomachs of all sizes of Nile perch caught by bottom trawling.

During the period August 1981-July 1982, *L. niloticus* from bottom trawl survey in the Nyanza Gulf of Lake Victoria fed on fish, insects, crustaceans and molluscs (Ogari, 1985). The post-larvae preferred microscopic crustaceans and insects, whereas the juveniles fed mainly on prawn, *Caridina nilotica*. With the increase in size *L. niloticus* became more piscivorous. The type of prey taken depended on both food availability and the size of the predator.

Ogutu-Ohwayo (1985) examined the food of the Nile perch in Lake Kyoga to estimate the extent of predation upon the populations of fish in the lake. Nile perch was observed to feed on invertebrates when young, changing to a piscivorous diet with increasing age. *Rastrineobola argentea* and *O. niloticus* were the most important fish prey with haplochromines and *L. niloticus* forming a less significant contribution to the diet. Ogutu-Ohwayo (1985.) further observed that since its introduction, the Nile perch had shifted from one type of prey food to another and that cannibalism had increased and the condition factor of the predator had decreased.

5.6.2. Food and feeding habits of *Oreochromis niloticus*

During this study no attempt was made to investigate the food and feeding habits of *O. niloticus* in the Uganda sector of Lake Victoria as an exhaustive study of this subject had just been completed (between December 1995 and December 1996) by Balirwa (1998) in the shallow habitats of northern Lake Victoria. Balirwa (1998) reported that feeding in most *O. niloticus* increased between 09:00 hrs and 13:00 hrs and the fish appeared not to feed during the night. Detrital material and insects, especially the chironomid larvae, were the most important regularly ingested items; the two items accounted for 65% of the mean stomach contents but the source of detritus appeared to depend on the distance from the shore. Generally, the small fish less than 15 cm in length ingested mostly invertebrates, but seasonal patterns explained most of the variation in ingested items in all fish (Balirwa, 1998). *O. niloticus* ingested mostly chironomids during the long dry season (December-March) when 192 chironomids per fish were recorded (Balirwa, 1998). Detrital material was more important during the short wet season (September-November) while in the short dry season (July-September), detrital material was \replaced by *Caridina* and molluscs which together made up at least 50% of the mean stomach contents during this period (July-September). Phytoplankton and higher plant material were among the main stomach contents but they never together made up more than 15% on average of the quantity of ingested items (Balirwa, 1998).

Gut analysis of *O. niloticus*, in the Kenya sector of Lake Victoria, showed that the fish does not necessarily choose the most abundant algal species in the water for its food (Njiru *et al.*, 2000a). This questions the earlier belief that the fish does not select algae because it feeds by gulping water within its vicinity. In the Nyanza Gulf fish fed mostly on blue green algae, though *Microcystis* spp. were not preferred. In the open waters, the fish always preferred *Nitzschia acicularis* even in presence of *Anabaena* blooms.

Another study in the Kenyan waters of Lake Victoria revealed that the diet of *O. niloticus* was currently more diverse, consisting of insects, fish, algae, plant material, bivalves and invertebrates (Njiru *et al.*, 2000b). Insects, mainly *Povilla adusta* and to a less extent *Trichoptera* nymphs, constituted the bulk of the food consumed by the fish throughout the lake. Fish, earlier not reported as a major diet for *O. niloticus*, featured prominently in the diet of *O. niloticus*. Among the fish encountered in the diet of *O. niloticus* were *L. niloticus, R. argentea, O. niloticus* and haplochromines; the most preferred fish was *R.*

argentea. There was no size preference for particular food items though *O. niloticus* juveniles less than 5 cm fed mainly on cladocerans. The authors argued that the feeding patterns observed in *O. niloticus* may be as a result of the species plasticity and response to changed ecological conditions prevailing in the lake following water hyacinth infestation.

5.7. Environmental parameters and other factors

During this study the water temperatures varied in the different habitats and seasons but generally ranged from 28.1°C at the surface to 24°C at the bottom. In Napoleon Gulf and Bugaia Island temperatures were higher during January-May and lower during June-September. This trend seemed to hold in most habitats except in the open offshore waters, like Lujabwa Island waters, which had constant temperature range.

Generally, Dissolved Oxygen (DO) concentrations were directly related to water temperature, decreasing with increasing water depth. DO distribution varied with depth, season and habitat during this study in 1999/2000. In Napoleon Gulf (16 m) and Buvuma Channel (12 m) DO decreased with increasing water depth during January 1999 to <2 mg l^{-1} at the bottom. In Bugaia Island waters (70 m), there was less than 1 mg l^{-1} DO recorded at the bottom during January to May 1999 while during June and August the DO values recorded from surface to the bottom were 6.0-5.6 mg l^{-1} and 7.7-3.7 mg l^{-1} mg l^{-1}; this indicates stratification in January-May and mixing during June-August.

DO in Lujabwa Island (40 m deep) waters decreased from 5.7 mg l^{-1} at the surface to 3.9 mg l^{-1} at the bottom during February 1999 and from 6.7 mg l^{-1} at the surface to 5.7 mg l^{-1} at the bottom, reflecting the presence of Oxygen even during the period other areas are stratified. In Busiji Pt-Mvuja Island (26 m), DO values decreased 1.2 mg l^{-1} at the bottom while in Damba Channel (30 m) the values decreased 2.5 mg l^{-1} at the bottom. In Sigulu Island waters (26 m deep) ,however, DO was 6.9 at the surface and 3.5 at the bottom.

It seems from above that Oxygen, a requirement for all living things, varied with water depth and temperature, season and habitats. The varied distribution of the fish during this study could have been due to the observed distribution of Oxygen. The high catches of fish in the 20-30 m depth area in Zone I is likely to be due to the presence of sufficient Oxygen in the area. The low abundance of fish in waters >25 m deep are partly due to insufficient or no Oxygen.

Hecky *et al.* (1994) reported that lack of Oxygen (anoxia) directly affects distribution of biotic organisms in Lake Victoria. The loss of approximately 50% of aerobic water volume in Lake Victoria since the 1960s (Hecky *et al.* 1994) reduces fish habitat, which can lower the potential fish production. Hypolimnetic anoxia is thought to have forced haplochromine and tilapiine fish species into the oxic surface waters where they experience heavy mortality by the introduced Nile perch (*Lates niloticus*) (Ogutu-Ohwayo, 1990a; Goldschmidt & Witte, 1992; Lehman *et al.*, 1998).

Kenyanya (2000) reported that Oxygen affects fish distribution and abundance. He observed that dissolved Oxygen concentrations in areas with water hyacinth infestation were low of the order 0.84 mg l^{-1}, to 1.5 mg l^{-1} at Awach River mouth. Fish catches were low and included *O. niloticus, Protopterus, Clarias*. These are fish that have a high tolerance to low Oxygen concentration.

Ochumba (1988) observed that fish kills in the Kenya sector of the lake affected mainly large fish and although a number of causes had been suggested, the pattern of the kills would suggest massive deOxygenation. This, therefore, confirms further that dissolved Oxygen affects the distribution and abundance of fish in Lake Victoria especially *L. niloticus*, which has low tolerance to low dissolved Oxygen levels.

6.0. CONCLUSIONS

6.1. Bottom trawl surveys.

During the bottom trawl surveys in 1999/2000:

- The fish catch was dominated by *Lates niloticus* (86.5% by weight), followed by *Oreochromis niloticus* (9.8%). *L. niloticus* was found in all areas surveyed while *O. niloticus* was restricted to waters <20 m deep.
- The highest catches of *L. niloticus* were obtained in Zone I (13.7±1.1 t km^{-2}), and Zone III had the lowest concentrations of fish (8.3±0.6 t km^{-}

^{2}). The highest catches of O. niloticus were obtained in Zone II (1.8±0.4 t km^{-2}) and the lowest catches were recorded in Zone III (0.5±0.1 t km^{-2}).

- Juveniles of *L. niloticus* of less than 6 cm TL were found in all areas surveyed and throughout the year, suggesting that breeding of *L. niloticus* takes place throughout the lake and year. Higher proportions of this size group were recorded during the rainy periods and in water <20 m deep.
- Whereas the stock densities have been reported to decrease with increasing water depth, the peak catches of *L. niloticus* in Zone I (30.3±6.3 t km^{-2}) were obtained in the 20-30 m water depth area.
- The fish stock densities (CPUA) continued to decline since research trawling began in 1969. CPUA in water 4-30 m deep declined from (36.2 t km^{-2}) for all fish during 1969/1971 to (8.8 t km^{-2}) for *L. niloticus* during the 1999/2000 surveys.
- The biomass of 119 491±13 412 t of *L. niloticus* and 12 193±3658 t of *O. niloticus* were estimated in the 4-40 m water depth zone. These estimates increased from 117 053±15 851 t in 1999 to 121 930±20 728 t in 2000 for *L. niloticus* and from 7316±2439 t in 1999 to 17 070±7316 t for *O. niloticus.*
- Juvenile *L. niloticus* measuring <50 cm TL (size at first maturity for male) constituted 72.5 % of the catch by weight while 27.5 % was from mature fish. Accordingly about 32 800 t of the 119 491 t estimated for bottom-dwelling *L. niloticus* in the 4-40 m water depth zones during the survey period 1999-2000 were mature fish.

- The bulk of the immature *L. niloticus* were caught in water <20 m deep (63.36 % by numbers) and in Zone III where they (immature fish) contributed 99% (by numbers) during 1999-2000.
- Exploitation rates for both *L. niloticus* (0.78) and *O. niloticus* (0.57) were high, especially in Zone III for *L. niloticus*
- Peak recruitment for both *L. niloticus* and *O. niloticus* occurred during the rainy season (March-May and August-November).
- The diet of *L. niloticus* varied with its size. *Caridina nilotica* formed the most important food item in juvenile fish up to 40 cm TL. The occurrence of fish in the diet of *L. niloticus* increased with increasing size of the fish specimens, becoming dominant in fish of 40 cm TL and contributing about 100% of the diet in fish of 90 cm TL.

6.2. Monofilament gill net surveys

- *L. niloticus* dominated the catches in the open deep water (93%) while *O. niloticus* dominated in the shallow inshore areas (45%).
- In the open deep water areas the nets set at the bottom did not catch fish.
- All *L. niloticus* were immature (<50 cm TL) while 60% (by numbers) of *O. niloticus* had not reached size at first maturity (22 cm TL).

6.3. Environmental parameters

- During this study the water temperature varied in the different habitats and seasons but generally ranged from 28.1°C at the surface to 24°C at the bottom. Dissolved Oxygen, a requirement for all living things, varied with water depth and temperature, season and habitats. DO was directly related to water temperature, decreasing with increasing water depth.
- The varied distribution of the fish during this study was attributed to the observed distribution of Oxygen.

7.0. RECOMMENDATIONS

- Fish processing factories – the major consumers of *L. niloticus* from Lake Victoria (>60% by weight) – should process *L. niloticus* of 50-85 cm total length. This will protect the immature fish (<50 cm TL) and the brood stock larger than 85 cm TL, especially the females, from exploitation.
- Regular surveys should be continued to monitor possible changes of the fish stocks in the lake, especially the distribution and abundance of *L. niloticus* and *O. niloticus*.

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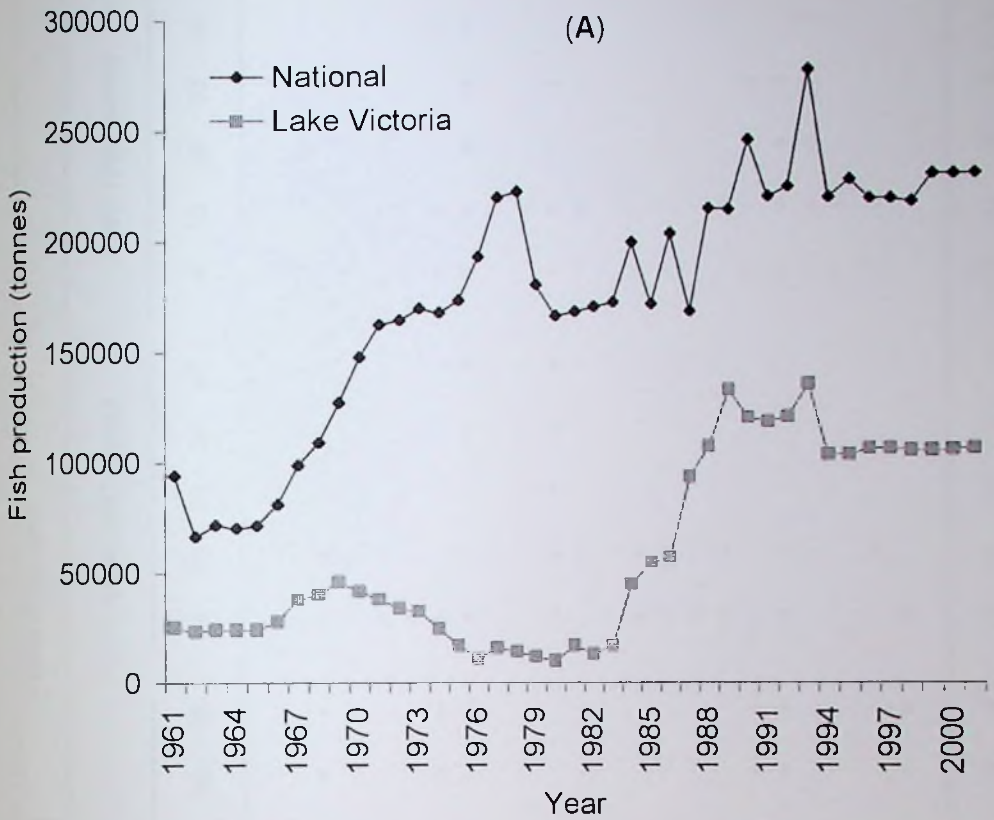

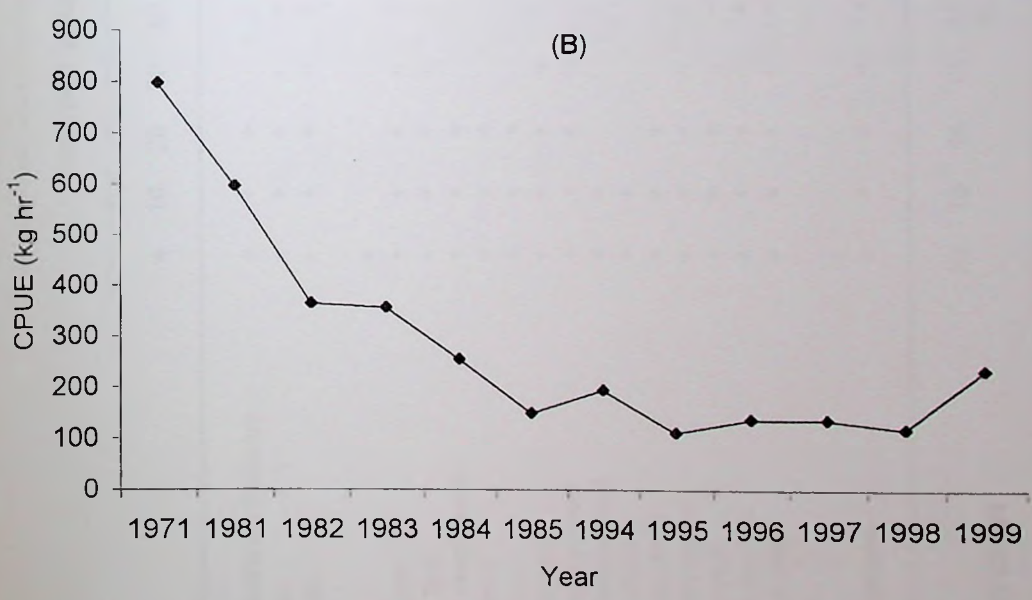

Appendix 1. Fish production in Uganda (A) and mean catch rates in the 4-30 m water depth area during botton trawl surveys in the Uganda sector of Lake Victoria (B).

Maximum water depths sampled were: 80 m in 1969-1971, 50 m in 1994-1997 and 80 m in 1997-1999.

	Water depth (m)																		
	1969-1971 survey								1994-1997 survey					1997-1999 survey					
Fish species	4	10	20	30	40	50	60	70	4	10	20	30	40	4	10	20	30	40	50
Aethiomastacembelus frenatus	+	+	+											+					
Bagrus docmak	+	+	+	+	+	+	+	+	+	+				+					
Barbus altianalis	+	+	+	+	+					+	+								
Barbus spp									+	+				+	+	+	+		+
Brycinus spp	+								+					+					
Clarias gariepinus	+	+	+	+	+	+	+	+	+					+	+				
Haplochromis spp	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gnathonemus longibarbis	+	+	+																
Labeo victorianus	+	+	+							+					+				
Lates niloticus	+	+	+						+	+	+	+	+	+	+	+	+	+	+
Mormyrus kannume	+	+	+	+	+	+	+	+		+					+				
Oreochromis esculentus	+	+	+	+															
Oreochromis leucostictus	+	+							+	+				+					
Oreochromis niloticus	+	+							+	+				+	+				
Oreochromis variabilis	+	+	+						+										
Protopterus aethiopicus	+	+	+	+	+	+			+	+					+				
Schilbe intermedius	+	+	+	+	+	+	+	+									+		
Synodontis afrofischeri	+	+	+	+	+	+	+	+	+	+				+	+	+	+		
Synodontis victoriae	+	+	+	+	+	+	+	+		+					+	+	+	+	
Tilapia rendalli															+				
Tilapia zillii	+									+				*	*				
Xenoclarias eupogon	+	+	+	+	+	+	+	+	+										
Total	20	18	16	11	10	9	8	8	12	13	3	2	2	11	12	5	6	3	3
Total per survey period					20						16					16			

Appendix 3. Mean catch rates (kg hr^{-1}) for fish caught (by water depth) during bottom trawl surveys in the [illegible] between January 1999 to December 2000. (0.00 = present in trace quantities of <0.005 kg hr^{-1}).
(mean catch rate = total catch/total number of hauls*60 minutes)

Fish species	Water Depth interval (metres) 4-10	10-20	20-30	30-40	40-50	50-60	Overall mean	Percen- tage
Aethiomastacembelus frenatus		0.00					0.00	0.00
Bagrus docmak	0.00						0.00	0.00
Barbus spp	0.00	0.02	0.04				0.02	0.01
Brycinus spp	0.00						0.00	0.00
Clarias gariepinus	0.24	0.04					0.07	0.03
Haplochromis spp	6.60	7.40	12.26	3.95	1.34	1.56	8.15	3.39
Labeo victorianus		0.00					0.00	0.00
Lates niloticus	214.39	165.23	274.45	223.63	11.49	0.18	207.60	86.47
Mormyrus kannume		0.00					0.00	0.00
Oreochromis leucostictus	0.00						0.00	0.00
O. niloticus	67.63	22.72					23.60	9.83
Protopterus aethiopicus	1.78	0.56					0.61	0.25
Schilbe intermedius					0.00		0.00	0.00
Synodontis afrofischeri	0.04	0.02	0.01				0.02	0.01
S. victoriae		0.00	0.00	0.01	0.21		0.00	0.00
Tilapia rendalli		0.02					0.01	0.00
T. zillii	0.06	0.02					0.02	0.01
Number of species caught	11	13	5	3	4	2	17	
Mean of total catch rate	290.74	196.03	286.76	227.59	13.04	1.74	240.10	
95% confidence level	±50.06	±31.33	±59.09	±71.51	±13.46	±7.1	±24.27	
Number of hauls	104	199	139	39	9	3	493	

Appendix 4. Length frequency distribution for *Lates niloticus* by zone and water depth during the bottom trawl surveys in the Uganda sector of Lake Victoria during 1999. (n = number of fish)

				Percentage by Water Depth Interval (metres)				
Year	Zone	Total Length (cm)	Average Weight (Kg)	4-10	10-20	20-30	30-40	4-40
1999	1	1-5	<0.02	14.57	7.23	4.41	9.01	5.63
		5-19	<0.10	34.45	52.20	57.71	53.15	55.30
		19-25	<0.20	17.36	14.62	7.10	5.86	8.65
		25-35	<0.50	19.61	13.52	15.41	14.86	15.44
		35-41	<1.00	5.04	4.56	6.98	9.46	6.66
		41-50	<2.00	4.49	3.30	5.42	3.19	5.00
		50-91	<10.00	4.48	3.78	2.77	4.01	3.06
		≥91	≥10.00		0.79	0.20	0.46	0.26
		n		357	633	4078	221	5289
	II	1-5	<0.02	16.49	10.28	6.34	1.25	10.67
		5-19	<0.10	57.59	61.92	62.85	41.27	59.63
		19-25	<0.20	14.27	14.90	9.54	17.08	13.37
		25-35	<0.50	8.69	9.08	12.92	18.36	10.53
		35-41	<1.00	1.53	1.94	3.89	8.60	2.72
		41-50	<2.00	0.73	1.09	2.53	8.50	1.48
		50-91	<10.00	0.65	0.72	1.89	4.70	1.54
		≥91	≥10.00	0.05	0.07	0.04	0.24	0.06
		n		29190	32130	25352	5046	91718
	III	1-5	<0.02	4.15	6.41	0.39	9.59	4.39
		5-19	<0.10	74.41	78.80	74.32	63.33	76.10
		19-25	<0.20	9.37	9.56	10.48	10.98	9.82
		25-35	<0.50	6.45	3.39	6.55	12.01	5.21
		35-41	<1.00	2.03	0.86	2.94	2.72	1.74
		41-50	<2.00	1.85	0.58	3.29	0.61	1.59
		50-91	<10.00	1.71	0.39	1.97	0.68	1.12
		≥91	≥10.00	0.03	0.01	0.06	0.08	0.03
		n		15880	36158	20791	2548	75477
	I-III	1-5	<0.02	12.16	8.22	3.72	4.26	7.77
		5-19	<0.10	63.28	70.66	67.18	48.98	66.70
		19-25	<0.20	12.58	12.13	9.73	14.73	11.67
		25-35	<0.50	7.99	6.13	10.48	16.14	8.35
		35-41	<1.00	1.73	1.40	3.75	6.66	2.41
		41-50	<2.00	1.16	0.84	3.08	5.71	1.80
		50-91	<10.00	1.05	0.57	2.00	3.33	1.24
		≥91	≥10.00	0.05	0.05	0.06	0.19	0.06
		n		45427	68921	50221	7915	172484

Appendix 5. Length frequency distribution for *Lates niloticus* by zone and water depth during the bottom trawl surveys in the Uganda sector of Lake Victoria during 2000. (n = number of fish)

Year	Zone	Total Length (cm)	Average Weight (Kg)	Percentage by Water Depth Interval (metres) 4-10	10-20	20-30	30-40	4-40
2000	1	1-5	<0.02	0.99	5.70	0.25	1.42	1.55
		5-19	<0.10	20.81	61.20	4.50	59.08	22.37
		19-25	<0.20	5.73	8.58	16.29	7.30	13.53
		25-35	<0.50	20.82	12.26	29.62	11.14	23.92
		35-41	<1.00	21.37	4.98	18.87	8.80	14.95
		41-50	<2.00	19.71	4.34	26.70	8.65	19.99
		50-91	<10.00	9.91	2.78	3.73	3.48	3.61
		≥91	≥10.00	0.66	0.16	0.04	0.13	0.08
		n		906	11706	36340	5337	54289
	II	1-5	<0.02	10.90	18.44	3.69	0.00	11.92
		5-19	<0.10	71.19	58.43	57.71	37.18	65.14
		19-25	<0.20	6.54	7.15	12.40	13.11	7.60
		25-35	<0.50	6.31	6.74	7.47	10.18	6.66
		35-41	<1.00	1.82	2.91	8.26	16.83	3.25
		41-50	<2.00	1.75	2.85	6.32	15.26	2.91
		50-91	<10.00	1.46	3.26	3.84	7.44	2.40
		≥91	≥10.00	0.03	0.22	0.31	0.00	0.12
		n		15511	7861	3567	511	27450
	III	1-5	<0.02	22.10	9.26	2.58	0.00	15.68
		5-19	<0.10	54.84	86.29	35.18	14.29	68.11
		19-25	<0.20	5.30	2.78	5.32	40.00	4.21
		25-35	<0.50	3.12	0.71	27.96	31.43	2.95
		35-41	<1.00	11.66	0.37	13.37	2.86	6.68
		41-50	<2.00	2.38	0.25	11.02	8.57	1.75
		50-91	<10.00	0.60	0.32	4.56	0.00	0.61
		≥91	≥10.00	0.00	0.02	0.01	2.85	0.01
		n		19437	16672	1316	35	37460
	I-III	1-5	<0.02	16.72	10.10	0.62	1.29	8.32
		5-19	<0.10	61.05	72.14	10.09	56.91	46.59
		19-25	<0.20	5.85	5.61	15.60	8.00	9.25
		25-35	<0.50	4.95	5.75	27.65	11.18	13.33
		35-41	<1.00	7.65	2.41	17.77	9.46	9.66
		41-50	<2.00	2.55	2.13	24.44	9.21	10.35
		50-91	<10.00	1.20	1.76	3.76	3.81	2.43
		≥91	≥10.00	0.03	0.10	0.07	0.14	0.07
		n		35954	36239	41223	5883	1199199

ndix 6. Length frequency distribution for *Lates niloticus* by zone and water depth during the bottom . trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 200 (n = number of fish)

Year	Zone	Total Length (cm)	Average Weight (Kg)	Percentage by Water Depth Interval (metres)				
				4-10	10-20	20-30	30-40	4-40
9/2000	1	1-5	<0.02	4.82	5.78	0.67	1.73	1.91
		5-19	<0.10	24.66	60.74	9.87	58.85	25.29
		19-25	<0.20	9.01	8.89	15.36	7.25	13.13
		25-35	<0.50	20.47	12.33	28.19	11.29	23.16
		35-41	<1.00	16.76	4.96	17.67	8.83	14.19
		41-50	<2.00	15.41	4.29	24.55	8.41	18.65
		50-91	<10.00	8.38	2.82	3.64	3.50	3.57
		≥91	≥10.00	0.49	0.19	0.05	0.14	0.10
		n		1263	12339	40418	5558	59578
	II	1-5	<0.02	14.55	11.88	6.02	1.13	10.96
		5-19	<0.10	62.30	61.20	62.20	40.90	60.90
		19-25	<0.20	11.58	13.43	9.89	16.71	12.03
		25-35	<0.50	7.87	8.62	12.25	17.61	9.64
		35-41	<1.00	1.63	2.13	4.43	9.36	2.84
		41-50	<2.00	1.09	1.42	3.01	9.13	2.04
		50-91	<10.00	0.93	1.22	2.13	4.94	1.51
		≥91	≥10.00	0.05	0.10	0.07	0.22	0.08
		n		44701	39991	28919	5557	119168
	III	1-5	<0.02	14.03	7.31	0.52	9.49	8.13
		5-19	<0.10	63.64	81.16	71.99	62.69	73.45
		19-25	<0.20	7.13	7.42	10.17	11.35	7.96
		25-35	<0.50	4.62	2.54	7.82	12.26	4.46
		35-41	<1.00	7.33	0.70	3.56	2.72	3.38
		41-50	<2.00	2.14	0.47	3.75	0.71	1.64
		50-91	<10.00	1.10	0.37	2.13	0.67	0.95
		≥91	≥10.00	0.01	0.03	0.06	0.11	0.03
		n		35317	52830	22107	2883	112937
	I-III	1-5	<0.02	14.18	8.22	2.32	2.99	7.99
		5-19	<0.10	62.30	70.66	41.44	52.37	58.49
		19-25	<0.20	9.61	12.13	12.38	11.86	10.68
		25-35	<0.50	6.65	6.13	18.22	14.03	10.38
		35-41	<1.00	4.34	1.40	10.08	7.85	5.37
		41-50	<2.00	1.77	0.81	12.71	7.20	5.29
		50-91	<10.00	1.11	0.60	2.79	3.54	1.72
		≥91	≥10.00	0.04	0.05	0.06	0.16	0.08
		n		81281	105160	91444	1398	291683

ndix 7. Composition of fish catch (percentage by weight) during multi-mesh monofilament gill net survey in the Uganda sector of Lake Victoria between April 2000 and September 2001.

		Percentage Composition (by weight)						
tion	Fish species	April 2000	Sep 2000	Feb 2001	Apr/May 2001	Jun/Jul 2001	Jul/Aug 2001	2000 -2001
Donald Bay (oito area)	*Astatoreochromis* sp	0.41				0.14		0.11
	Brycinus jacksonni	1.85	5.31	4.06	7.46	1.82	7.49	4.24
	Clarias gariepinus	2.76		6.17				1.58
	Haplochromis spp	11.34	12.14	33.06	24.49	24.86	11.98	18.96
	Lates niloticus	27.21	21.45	18.72	25.24	21.16	10.75	21.04
	Oreochromis leucostictus		0.02	0.59		1.74	0.53	0.50
	O. niloticus	50.52	57.68	36.83	34.64	47.22	65.04	49.72
	Synodontis afrofischeri					0.10		0.02
	Tilapia zillii	5.91	3.40	0.57	8.17	2.96	4.21	3.83
	Total weight (kg)	42.12	46.02	36.82	18.52	38.67	27.14	209.29
olleon Gulf	*Astatoreochromis* sp				2.65			0.58
	Brycinus jacksonni		1.38	2.49	1.97	2.19	2.03	2.24
	Clarias gariepinus			23.15				6.01
	Haplochromis spp		11.49	29.17	18.92	21.33	8.61	23.85
	Lates niloticus		2.51	3.31	1.22	3.31	1.71	2.85
	Oreochromis leucostictus		3.28	2.37	7.69	6.07	6.00	5.09
	O. niloticus		63.81	28.82	51.31	49.65	47.08	44.13
	O. variabilis		0.78		0.54	2.78		0.70
	Tilapia zillii		16.75	10.59	15.70	14.67	34.57	14.54
	Total weight (kg)		25.55	34.56	29.28	[illegible]	9.40	[illegible]
ding Bay	*Astatoreochromis* sp				13.09			3.48
	Brycinus jacksonni		6.31	[illegible]	[illegible]	[illegible]	11.05	[illegible]
	Haplochromis spp		5.38	25.37	[illegible]	[illegible]	75.79	24.68
	Lates niloticus	100.00	8.73	2.94	3.74	14.03	3.40	14.30
	Oreochromis leucostictus		15.61	5.86		30.17		5.93
	O. niloticus		54.15	47.92	47.39	[illegible]	19.74	38.74
	O. variabilis				0.69			0.18
	Tilapia zillii		9.34	16.55	4.40	8.77		6.20
	Total weight (kg)	4.36	7.57	7.82	[illegible]	[illegible]	10.46	48.04

endix 7. (continued)

ation	Fish species	Percentage Composition (by weight)					
		May 2000	Oct 2000	April 2001	Jul 2001	Sep 2001	2000 -2001
bbe area	*Astatoreochromis* sp					0.48	0.04
	Brycinus jacksonni	0.79	1.12	1.12			0.91
	Haplochromis spp	9.26	6.45	17.64	46.9	28.61	14.26
	Labeo victorianus	0.58					0.13
	Lates niloticus	22.71	16.50	52.81	9.82	65.02	35.37
	Oreochromis leucostictus		1.89	1.78			1.19
	O. niloticus	58.38	62.29	12.04	11.77	3.20	36.39
	O. variabilis					1.64	0.15
	Tilapia zillii	8.28	11.76	14.61	31.51	1.05	11.55
	Total weight (kg)	26.04	32.82	41.29	3.03	10.33	113.51

'diix 8. Index of abundance of fish stocks (by water depth) during the bottom trawl surveys in the Uganda sector ofLake Victoria between January 1999 and December 2000.

Year	Zone	Water Depth Interval (m)	No. of Hauls	Mean catch ($kg\ Haul^{-1}$)			Standing crop ($tonnes\ km^{-2}$)		
				All species	*L. niloticus*	*O. niloticus*	All species	*L. niloticus*	*O. niloticus*
2000	I	4-10	9	158.97	119.52	38.22	14.45	10.86	3.47
		10-20	35	125.30	117.10	4.92	11.39	10.64	0.45
		20-30	22	156.00	151.35		14.18	12.85	
		30-40	17	113.11	111.42		0.36	10.13	
	II	4-10	62	132.38	84.93	42.83	12.03	7.72	3.89
		10-20	69	113.47	98.59	9.21	10.31	8.96	0.84
		20-30	59	125.96	114.12		11.45	10.37	
		30-40	18	151.05	148.03		13.73	.13.46	
		40-50	3	12.12	10.34		1.10	0.94	
	III	4-10	34	175.40	152.74	16.92	15.95	13.88	1.54
		10-20	91	85.65	64.55	17.15	7.79	5.87	1.56
		20-30	55	115.77	114.60		10.52	10.42	
		30-40	8	53.91	53.26		4.90	4.84	
		40-50	6	4.94	4.38		0.45	0.39	
	All zones	4-10	105	148.59	109.85	34.04	13.51	9.99	3.00
		10-20	195	102.61	88.02	12.11	9.33	8.00	1.10
		20-30	136	142.87	136.51		12.99	12.41	
		30-40	43	117.98	115.92		10.72	10.54	
		40-50	9	7.34	6.33		0.67	0.58	
1999	All zones	4-10	49	147.53	123.97	18.65	13.41	11.27	1.70
		10-20	97	99.73	79.30	15.80	9.07	7.21	1.44
		20-30	80	135.50	126.80		12.32	11.53	
		30-40	24	117.64	115.48		10.69	10.50	
		40-50	5	7.75	6.68		0.70	0.61	
2000	All zones	4-10	56	149.52	97.50	47.51	13.59	8.86	4.32
		10-20	98	105.46	92.68	8.45	9.59	8.42	0.77
		20-30	56	153.40	150.37		13.94	13.67	
		30-40	19	118.40	116.51		10.76	10.59	
		40-50	4	6.81	5.89		0.62	0.54	

ndix 9. Index of abundance of fish stocks (by season) during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.
[0.00 = Trace quantities of <0.005 kg Haul^{-1}]

Year	Season	Zone	No. of Hauls	Mean catch (kg Haul^{-1}) All species	Mean catch (kg Haul^{-1}) *L. niloticus*	Mean catch (kg Haul^{-1}) *O. niloticus*	Standing crop (tonnes km^{-2}) All species	Standing crop (tonnes km^{-2}) *L. niloticus*	Standing crop (tonnes km^{-2}) *O. niloticus*
1999	1	ALL	68	111.22	107.39	1.58	10.11	9.76	0.14
		I	18	58.02	55.94	0.46	5.27	5.08	0.04
		II	18	105.53	100.75	1.16	9.59	9.16	0.11
		III	32	144.36	140.07	2.44	13.12	12.79	0.22
	2	ALL	83	104.60	94.14	6.46	9.51	8.56	0.59
		I							
		II	63	101.88	90.90	8.03	9.26	8.26	0.73
		III	20	113.19	104.35	1.52	10.29	9.49	0.14
	3	ALL	58	142.77	116.74	21.80	12.98	10.61	1.98
		I	5	21.99	21.87	0.00	2.00	1.99	0.00
		II	28	175.46	166.15	4.66	15.95	15.10	0.42
		III	25	130.32	81.49	45.35	11.85	7.41	4.12
	4	ALL	46	150.53	126.09	8.01	13.68	11.46	0.73
		I	15	110.02	103.77	3.23	10.00	9.43	0.29
		II	31	170.13	136.89	10.33	15.46	12.44	0.94
		III							
2000	1	ALL	70	91.87	83.00	6.69	8.35	7.54	0.61
		I	13	222.80	217.77	2.83	20.25	19.80	0.26
		II	16	62.18	43.87	14.47	5.65	3.99	1.32
		III	41	61.95	55.54	4.88	5.63	5.05	0.44
	2	ALL	59	141.64	127.57	8.55	12.88	11.60	0.78
		I	34	191.23	180.36	6.10	17.38	16.39	0.55
		II	20	67.27	50.44	10.80	6.11	4.59	0.98
		III	5	101.99	77.19	16.26	9.27	7.02	1.48
	3	ALL	81	121.00	92.43	24.62	11.00	8.40	2.24
		I	2	71.53	64.70	3.73	6.50	5.88	0.34
		II	22	156.59	82.30	69.45	14.23	7.48	0.31
		III	57	109.01	97.31	8.06	9.91	8.85	0.73
	4	ALL	34	144.67	127.59	14.23	13.15	11.60	1.29
		I	14	147.78	131.41	14.93	13.43	11.95	1.36
		II	20	142.49	124.92	13.75	12.95	11.36	1.25
		III							
2000	1	ALL	138	101.41	95.02	4.17	9.22	8.64	0.38
	2	ALL	142	119.99	108.03	7.33	10.91	9.82	0.67
	3	ALL	138	124.55	102.96	17.62	11.32	9.36	1.60
	4	ALL	108	130.22	111.81	10.09	11.84	10.16	0.92

Seasons: 1 = December-February (dry), 2 = March-May (rainy), 3 = June-July (dry), 4 = August-November (rainy) dix 10. Index of abundance of fish stocks (by grid and season) during the bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000. [Seasons: 1 = December-February (dry), 2 = March-May (rainy), 3 = June-July (rainy), 4 = August-November (rainy)]

n	Grid	Hauls	Tonnes km^{-2} *L. niloticus*	Tonnes km^{-2} *O. niloticus*
1	A07	5	1.1	0.9
	A08	12	1.8	
	B04	3	4.2	
	B06	1	3.9	
	B07	21	7.0	1.1
	B08	9	16.3	
	B09	8	2.6	
	B10	16	13.5	0.3
	C03	19	9.5	2.2
	C04	7	0.6	
	C05	3	0.1	
	C07	2	0.1	
	C09	2	12.6	
	D03	11	8.3	0.8
	E02	9	35.8	
	E03	10	12.1	
2	A07	2	1.8	
	B04	6	5.5	0.2
	B05	3	5.1	
	B06	1	0.8	
	B07	8	7.2	1.1
	B08	5	0.8	
	B09	4	7.6	
	B10	6	23.5	0.1
	C03	28	6.9	1.9
	C04	17	8.4	
	C05	11	7.0	
	D03	20	6.8	1.3
	E02	12	13.8	0.2
	E03	6	36.1	
	F02	8	10.6	

Season	Grid	Hauls	Tonnes km^{-2} *L. niloticus*	Tonnes km^{-2} *O. niloticus*
3	A07	3	1.1	
	A08	7	6.4	1.3
	B04	7	6.1	1.3
	B05	3	13.2	
	B06	2	19.8	
	B07	10	9.8	0.7
	B09	4	0.4	
	B10	7	13.3	1.5
	C02	1		6.9
	C03	21	7.8	6.1
	C04	13	14.7	
	C05	9	4.4	
	D02	1		2.6
	D03	4	7.5	0.6
	D04	3	22.7	
	E03	5	2.5	
4	A07	6	7.5	0.7
	A08	7	2.8	
	B04	5	3.0	0.3
	B05	3	9.6	
	B06	1	15.0	
	B07	10	7.0	0.1
	B08	6	18.2	0.1
	B09	4	9.7	0.1
	B10	8	11.5	10.5
	C03	18	13.4	2.2
	C04	13	15.7	
	C05	8	9.3	
	C07	1	14.2	
	C09	2	31.0	
	D02	3		3.9
	D03	11	9.7	
	E02	6	5.1	
	E03	11	9.1	

between January 1999 and December 2000.

Period	Water Depth Interval (m)	Estim. area (km-2)	No. of Hauls	Standing crop (tonnes km^{-2})			Biomass (tonnes±95% Conf. level)		
				All species	*L. niloticus*	*O. niloticus*	All species	*L. niloticus*	*O. niloticus*
1999	4-10	3744	49	13.4±3.4	11.3±3.2	1.7±0.6	50170±12730	42307±11981	6365±2246
	10-20	3584	99	8.1±1.8	7.1±1.6	0.6±0.3	29030±6451	25446±5734	2150±1075
	20-30	2842	80	12.3±3.1	11.5±2.9		34957±8810	32683±8242	
	30-40	2025	24	10.7±4.9	10.5±4.8		21668±9923	21263±9720	
	4-40	12193	252	10.7±1.4	9.6±1.3	0.6±0.2	130465±17070	117053±15851	7316±2439
2000	4-10	3744	56	13.6±3.6	8.9±2.6	4.3±2.5	50918±13478	33322±9734	16099±9360
	10-20	3584	99	9.5±1.9	8.3±1.9	0.8±0.3	34048±6810	29747±6810	2867±1075
	20-30	2842	56	13.9±5.4	13.7±5.4		39504±15347	38935±15347	
	30-40	2025	19	10.8±5.0	10.6±5.1		21870±10125	21263±10328	
	4-40	12193	230	11.7±1.8	10.0±1.7	1.4±0.6	142658±21947	121930±20728	17070±7316
1999	4-10	3744	105	13.5±2.0	10.0±2.0	3.1±1.3	50544±24386	37440±24386	11606±4867
-2000	10-20	3584	198	8.8±1.2	7.7±1.2	0.7±0.2	31539±4301	27597±4301	2509±717
	20-30	2842	136	13.0±2.8	12.6±2.8		36946±7958	35809±7958	
	30-40	2025	43	10.7±3.3	10.5±3.3		21668±6683	21263±6683	
	4-40	12193	482	11.2±1.1	9.8±1.1	1.0±0.3	136562±13412	119491±13412	12193±3658

Victoria between January 1999 and December 2000. [0.00 = Trace quantities of <0.005%]

Period	Water Depth Interval (m)	Estimated area (km^2)	No. of Hauls	Mean catch (kg $Haul^{-1}$)			Standing crop (tonnes km^{-2})			Biomass (tonnes)		
				All species	*L. niloticus*	*O. niloticus*	All species	*L. niloticus*	*O. niloticus*	All species	*L. niloticus*	*O. niloticus*
1999	4-10	3744	104	148.59	109.85	34.08	13.51	9.99	3.10	50570.04	37385.55	11598.54
-2000	10-20	3584	199	100.54	84.30	11.87	9.14	7.66	1.08	32754.78	27463.98	3867.11
	20-30	2842	139	141.82	135.51		12.89	12.32		36637.8	35007.67	
	30-40	2025	39	117.94	115.94		10.72	10.54		21709.71	21341.56	
									Total	141672.33	121198.76	15465.65

Estimated biomass distribution for *Lates niloticus* in the 4-40 m water depth zone, 1999-2000

Total length Interval (m)	Weight (percentage)	Biomass (tonnes)
.1-10	0.98	1186
10-50	64.44	78100
50-100	31.32	37959
>100	3.26	3951

Total length (cm)	Numbers (%)	Weight (%)
1-10	38.33	0.98
10-20	38.25	9.11
20-30	13.23	14.56
30-40	6.01	21.06
40-50	2.74	19.71
50-60	0.92	12.79
60-70	0.26	6.12
70-80	0.12	4.58
80-90	.0.06	4.38
90-100	0.04	3.45
100-110	0.01	1.43
110-120	0.01	0.71
120-130	0.00	0.15
130-190	0.00	0.97

Appendix 13. Items ingested by *Lates niloticus* caught in different grids during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

		Items ingested (percentage occurrence)																		
Period	Grid	All fish specimens	*Caridina*	*Chaoborus*	*Chironomus*	*Clarias*	Detritus	*Ephemeroptera*	*Fish Remains*	*Haplochromis*	*Lates*	*Mastacembelus*	*Odonata*	*Oreochromis*	*Povilla*	*Protopterus*	*Rastrineobola*	Snails	*Synodontis*	Empty stomachs
1999	A08																			
	B04	140	14.3	6.4	0.0	0.7			25.3	10.4	7.1	0.0	3.6	2.6	2.9		25.0	0.7	0.0	1.4
	B05	133	86.5	0.0	0.0	0.0			7.5	2.3	0.0	0.0	0.0	0.0	0.0		0.8	0.0	0.0	3.0
	B06																			
	B07	114	38.6	0.0	5.3	0.9			18.4	4.4	0.9	0.0	0.9	0.8	0.9		16.7	0.0	0.0	9.6
	B08	24	100	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
	B09	87	92.0	0.0	0.0	0.0			0.0	4.6	2.3	0.0	0.0	0.0	0.0		0.0	0.0	0.0	1.1
	B10	210	57.6	0.0	0.0	0.0			25.2	11.9	1.9	0.0	0.0	0.0	0.0		1.4	0.0	0.0	1.9
	C03	393	19.6	1.0	0.0	0.0			24.7	13.0	5.3	0.0	4.6	1.2	0.3		27.2	0.0	0.0	4.1
	C04	189	57.7	0.0	0.0	0.0			13.2	16.4	1.1	0.0	0.0	0.0	0.0		3.7	0.0	0.5	7.5
	C05	185	85.9	0.0	0.0	0.0			5.4	1.1	2.2	0.0	0.0	0.0	0.0		2.7	0.0	0.0	3.2
	D03	202	20.3	3.5	2.5	0.0			20.3	7.9	5.4	0.5	1.0	0.5	0.0		32.7	0.0	0.0	5.9
	D04	62	62.9	0.0	0.0	0.0			14.5	3.2	1.6	0.0	1.6	2.6	0.0		12.9	0.0	0.0	3.2
	D05	21	90.5	0.0	0.0	0.0			4.8	0.0	0.0	0.0	0.0	0.0	0.0		4.8	0.0	0.0	0.0
	E02	57	68.4	0.0	0.0	0.0			8.8	3.5	0.0	0.0	0.0	0.0	0.0		10.5	0.0	0.0	8.8
	E03	54	77.8	0.0	0.0	0.0			1.9	11.1	0.0	0.0	0.0	0.0	0.0		5.6	0.0	0.0	22.2
	F02																			
2000	A08	60	66.7	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1.7		0.0	0.0	0.0	0.0	10.0	0.0		0.0
	B04	41	29.3	0.0	0.0	0.0	0.0	0.0	22.0	9.8	0.0		9.8	23.8	0.0	0.0	26.8	0.0		2.4
	B05																			
	B06	23	69.6	0.0	0.0	0.0	0.0	0.0	13.0	17.4	0.0		0.0	0.0	0.0	0.0	0.0	0.0		21.7
	B07	181	53.6	3.3	0.0	0.0	1.7	0.0	9.9	6.6	2.8		2.8	1.5	0.6	0.0	9.4	0.6		7.2
	B08	60	73.3	0.0	0.0	0.0	0.0	0.0	1.7	6.7	1.7		3.3	5.6	0.0	0.0	11.7	0.0		1.7
	B09	45	48.9	0.0	0.0	0.0	0.0	0.0	22.2	11.1	4.4		0.0	0.0	0.0	0.0	4.4	0.0		4.4
	B10	195	50.8	0.0	0.0	0.5	0.0	0.0	14.4	17.4	4.6		2.6	1.3	0.0	0.0	4.6	0.0		5.1
	C03	322	25.5	3.7	0.3	0.0	0.0	0.3	17.4	19.6	2.8		1.9	0.6	0.0	0.3	23.3	0.0		4.7
	C04	202	47.0	0.5	0.0	0.0	0.0	0.0	8.9	11.4	1.5		1.0	0.5	0.0	0.0	12.9	0.0		14.4
	C05	20	65.0	0.0	0.0	0.0	0.0	0.0	10.0	5.0	0.0		0.0	0.0	0.0	0.0	10.0	0.0		0.0
	D03	232	25.4	6.0	0.0	0.0	0.0	0.0	18.1	10.8	3.0		0.4	0.2	1.3	0.0	29.3	0.0		5.6
	D04																			
	D05																			
	E02	160	50.6	0.0	0.0	0.0	0.0	0.0	10.6	5.0	1.3		0.0	0.0	0.0	0.0	19.4	0.0		13.8
	E03	120	75.8	0.0	0.0	0.0	0.0	0.0	4.2	1.7	1.7		0.0	0.0	0.0	0.0	1.7	0.0		15.0
	F02	80	52.5	0.0	0.0	0.0	0.0	0.0	12.5	12.5	1.3		0.0	0.0	0.0	0.0	12.5	0.0		8.8

Appendix 14. Items ingested (grouped) by *Lates niloticus* caught in different grids during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

		Items ingested (Percentage occurrence)					
Grid	All fish specimens	**Fish and fish remains	**Insects	*Caridina nilotica*	Detritus	Snails	Empty stomachs
A08	60	31.7		66.7			1.7
B04	181	74.2	12.1	12.1		0.5	1.1
B05	133	10.5		86.5			3.0
B06	23	30.4		47.8			21.7
B07	295	34.8	6.9	47.8	1.0	0.3	9.2
B08	84	19.4	2.4	77.0			1.2
B09	132	18.9		77.3			3.8
B10	405	41.6	1.3	54.3			2.7
C03	715	68.0	6.0	22.2			3.7
C04	391	35.0	0.7	52.2			12.1
C05	205	12.7		83.9			3.4
D03	434	64.2	7.4	23.0			5.4
D04	62	34.9	2.2	62.9			
D05	21	9.5		90.5			
E02	217	32.7		55.3			12.0
E03	174	12.1		76.4			11.5
F02	80	38.8		52.5			8.8

** Fish and fish remains: *Clarias* sp., *Haplochromis* spp,, *Lates* sp., *Mastacembelus* sp., *Oreochromis* sp, *Protopterus* sp., *Rastrineobola* sp., *Synodontis* sp., fish remains.

** Insects: *Chaoborus, Chironomus,* Ephemeroptera, *Povilla, Odonata.*

Appendix 15. Items ingested by different sizes of *Lates niloticus* caught during bottom trawl surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

			Items ingested (percentage occurrence)																
Period	Grid	All fish specimens	*Caridina*	*Chaoborus*	*Chironomus*	*Clarias*	Detritus	*Ephemeroptera*	*Fish Remains*	*Haplochromis*	*Lates*	*Mastacembelus*	*Odonata*	*Oreochromis*	*Povilla*	*Protopterus*	*Rastrineobola*	Snails	*Synodontis*
1999	<10	145	80.6	6.2	0.0	0.0			8.3	0.0	0.0	0.0	0.0	0.0	2.1		2.8	0.0	0.0
	10-20	451	76.5	2.0	2.2	0.0			11.6	2.0	0.4	0.0	1.6	0.0	0.4		3.3	0.0	0.0
	20-30	428	54.9	0.2	0.0	0.0			16.6	7.2	2.8	0.0	3.7	0.2	0.2		14.2	0.0	0.0
	30-40	359	40.1	0.0	0.0	0.3			21.8	11.4	1.4	0.0	0.8	0.0	0.0		24.2	0.0	0.0
	40-50	203	35.5	0.0	0.5	0.5			18.7	18.7	2.0	0.0	0.0	0.0	0.0		23.6	0.5	0.0
	50-60	102	19.6	0.0	0.0	0.0			23.5	18.6	10.8	0.0	1.0	0.0	0.0		26.5	0.0	0.0
	60-70	31	3.2	0.0	0.0	0.0			25.8	29.0	22.6	0.0	0.0	0.0	0.0		19.4	0.0	0.0
	70-80	32	6.3	0.0	0.0	0.0			25.0	37.5	18.8	3.1	0.0	0.0	0.0		6.2	0.0	3.1
	80-90	15	6.7	0.0	0.0	0.0			20.0	13.3	46.7	0.0	0.0	0.0	0.0		13.3	0.0	0.0
	90-100	8	0.0	0.0	0.0	0.0			37.5	12.5	25.0	0.0	0.0	0.0	0.0		25.0	0.0	0.0
	100-150	6	0.0	0.0	0.0	0.0			16.7	0.0	83.3	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	>150	3	0.0	0.0	0.0	0.0			66.7	0.0	0.0	0.0	0.0	33.3	0.0		0.0	0.0	0.0
2000	<10	268	76.9	7.1	0.0	0.0	0.4	0.4	7.8	1.1	0.0		0.7	0.4	0.7	0.0	4.5	0.0	
	10-20	390	67.7	2.3	0.5	0.0	0.0	0.0	12.8	2.6	0.0		3.3	0.3	0.0	0.0	10.5	0.0	
	20-30	268	54.1	0.7	0.0	0.0	0.0	0.0	16.0	13.1	0.4		2.2	0.0	0.0	0.0	13.5	0.0	
	30-40	253	44.7	1.2	0.0	0.0	0.4	0.0	13.4	15.8	0.8		1.6	0.0	0.0	0.0	22.1	0.0	
	40-50	208	28.4	0.0	0.0	0.0	0.0	0.0	19.2	21.6	2.4		0.0	0.5	0.0	0.0	27.4	0.5	
	50-60	124	8.8	0.0	0.0	0.0	0.0	0.0	10.5	35.5	6.5		0.0	2.4	0.0	0.0	35.5	0.8	
	60-70	47	4.3	0.0	0.0	0.0	0.0	0.0	21.3	34.0	12.8		0.0	0.0	0.0	0.0	27.6	0.0	
	70-80	26	0.0	0.0	0.0	0.0	0.0	0.0	19.2	34.6	30.8		0.0	0.0	0.0	0.0	15.4	0.0	
	80-90	16	0.0	0.0	0.0	0.0	0.0	0.0	12.5	25.0	37.5		0.0	0.0	0.0	12.5	12.5	0.0	
	90-100	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	25.0		0.0	25.0	0.0	0.0	0.0	0.0	
	100-150	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	60.0		0.0	0.0	0.0	0.0	20.0	0.0	
	>150	2	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0		0.0	0.0	0.0	0.0	0.0	0.0	

Appendix 16. Items ingested (grouped) by different sizes of *Lates niloticus* caught during bottom traw surveys in the Uganda sector of Lake Victoria between January 1999 and December 2000.

Total length (cm)	All fish specimens	Items ingested (percentage occurrence)					
		**Fish and Fish remains	**Insects	*Caridina nilotica*	Detritus	Snails	Empty stomachs
<10	413	12.8	8.7	75.1	0.2		3.1
10-20	841	22.6	6.4	71.0			
20-30	696	41.7	3.7	54.6			
30-40	612	56.2	1.6	42.0	0.2		
40-50	411	67.4	0.2	31.9		0.5	
50-60	226	85.4	0.4	13.3		0.4	0.4
60-70	78	96.2		3.8			
70-80	58	96.6		3.4			
80-90	31	93.5		3.2			3.2
90-100	12	100.0					
100-150	11	90.9					9.1
>150	5	100.0					

** Fish and fish remains: *Clarias* sp., *Haplochromis* spp., *Lates* sp., *Mastacembelus* sp., *Oreochromis* sp., *Protopterus* sp., *Rastrineobola* sp., *Synodontis* sp., fish remains.

** Insects: *Chaoborus, Chironomus,* Ephemeroptera, *Povilla, Odonata.*