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ASSESSMENT OF THE STATUS OF THE STOCK AND FISHERY OF NILE PERCH IN LAKE VICTORIA, UGANDA

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ABSTRACT

Fish stocks in Lake Victoria (East Africa) were boosted in the 1950s with the introduction of four tilapiine species and Nile perch (*Lates niloticus)* following the collapse of the native fishery due to over-fishing. With annual fisheries production close to 500,000 tons, Lake Victoria remains the most important source of fisheries resources for the three East African countries sharing it (Kenya, Tanzania and Uganda). It took close to 30 years for the introduced species to produce substantial catches reaching a peak in the early 1990s. Current trends indicate that the stocks of the introduced Nile perch are declining. In this study, data collected from trawl surveys between 1997 and 2001, catch assessment surveys (CAS) 2003, and frame survey data (2002), together with published information were used to assess the current status of the stocks and fishery of Nile perch in the Ugandan part of the lake.

This study establishes that of all the factors affecting catch rates from trawl surveys, depth has a profound influence and that variation in years was significant and shows a declining trend. Beach seines harvest a larger amount of juveniles and result in reduced YPR and SSB/R. Revised zoning of the lake based on depth for monitoring purposes is therefore recommended as well as support of methods that will enhance reduction in illegal gears and consequent reduction in harvesting of juveniles. Possible approaches suggested include increased surveillance and co-management.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

Fisheries based on non-native (introduced) fish species in many aquatic environments have been of interest to scientists and managers the world over. Important aspects range from species' establishment and performance in their new habitats, through to environmental impact and socio-economical benefits associated with the alien species. Nile perch *(Lates niloticus)* was introduced in Lake Victoria (East Africa) amid controversy by the colonial government to boost the fisheries production of the lake. The introduction of Nile perch in Lake Victoria was first proposed by Graham (1929) to feed on what was termed "trash fish" (native small and bony haplochromine cichlids) and convert into a larger fish of greater commercial and recreational value (Anderson 1961). Nile perch did exactly what was anticipated (Muhoozi 2002). However, proponents of introducing Nile perch in Lake Victoria overlooked the possibility that the small fish in the lake would become over preyed upon, which eventually happened. Although many fish stocks in Lake Victoria had declined in the period before the establishment of Nile perch stock, a dramatic increase in the population size of Nile perch in the 1980s roughly coincided with the drastic decline or disappearance of many indigenous species (Witte *et al*. 1992). There was hence a shift from the former multi-species fishery of the lake to a new form of fishery based on introduced species in the lake.

Lake Victoria is the most important source of inland fishery production for the three East African states (Uganda, Kenya, and Tanzania) sharing the lake. Despite the fact that the other two countries, Tanzania and Kenya, have access to fishable ocean waters, fish catches from Lake Victoria still make up more than 90% of their total fisheries production (Kulindwa 2001). The lake was initially fished down in the first half of the 20th century; non-native fish introductions were recommended that resulted in the eventual demographic dominance of the Nile perch, an alien species in the lake. Nile perch stocks tremendously increased resulting in dramatic changes in the ecology of the lake. Despite the fact that Nile perch was introduced in Lake Victoria as early as 1960, it was not until the 1980s that substantial catches started being realized. Catches from the Ugandan part of the lake rapidly increased in a period of one decade from less than 15,000 mt in 1982 to over 120, 000 mt in 1992 (the period of the Nile perch boom). However, despite continuous increase in annual catches, signs of growth and recruitment over fishing had started manifesting by the mid 1980s (Asila and Ogari 1988). Warning of over fishing signs continued throughout the 1990s but during the same period prominent scientific studies and management efforts were all directed at biodiversity issues of the lake, which had crumbled following the Nile perch boom.

Two decades after the immense rise of Nile perch in Lake Victoria, it is now evident that the species is being over-fished (Muhoozi 2002). At the same time, some of the native species that had dwindled to very low population levels, some once threatened with extinction, are now re-emerging (Schindler *et al*. 1998, Balirwa *et al.* 2003). Many studies carried out from the late 1990s to the early 2000s indicate that proper management of the Nile perch fishery can enhance both commercial benefits from the fishery and the biodiversity of the lake (Schindler *et al*. 1998). Putting together all this published information and analysing related data that has been collected in recent times should provide clearly defined options to manage this important fishery threatened with imminent collapse.

In this study, published information and a thorough analysis of available data were used to evaluate the current state of the Nile perch fishery in the Uganda portion of the lake. Particular emphasis was placed on the effects of harvesting immature fish.

1.2 Statement of the problem

Over-fishing, the consequent collapse of the native fish stocks in Lake Victoria and the resulting biological and socio-economic effects are well documented facts in both scientific and administrative communities. Low fish stocks undoubtedly led to the introduction of alien species to boost fisheries production. The introduction of Nile perch resulted in more than a five-fold increase in the amount of fish protein available to local communities and increased income and employment opportunities. Looming threats of juvenile over-fishing that could ultimately lead to the collapse of this lucrative fishery should not be under estimated.

1.3 Significance of this study

A lot of information has been collected, geared at the management of fisheries in Lake Victoria. The key issue now is whether these efforts have resulted in improved management and consequently translated into improved fish yields. This report assesses the current status of stocks and fishery exploitation patterns. The results indicate that urgent improvements in the management scheme of the Nile perch fishery are necessary. These improvements would benefit all the fisheries stakeholders in the region. Information generated from this study could form a starting point for other scientists interested in undertaking similar studies in fisheries targeting other species in the lake.

1.4 Scope of study

The study is designed to investigate the current status of the Nile perch fishery on the Ugandan part of Lake Victoria. Published information on the current fishing factors and trends in stocks over time are evaluated and comparisons drawn from available data. A model is designed to investigate changes in stocks, gear types and resultant yield indices. Data and survey methods are also evaluated, deficiencies are pointed out and improvements suggested.

1.5 The biology of Nile perch

Nile perch is a silver coloured Centropomidae occurring naturally in the Ethiopian region, lakes Albert (Uganda) and Turkana (Kenya). It has been reported to grow to over 190 cm in total length (TL) and over 200 kg fresh body weight (fish base). Nile perch inhabits mainly fresh water systems but has also been reported in brackish waters of Lake Mariout near Alexandria (Egypt). The species is thought to be a pelagic spawner in sheltered sites, eggs and larval stages have been found in the pelagic zone of the lake (Asila and Ogari 1988). Juveniles aggregate in the shallow areas of the lake (Asila and Ogari 1988; Ogutu-Ohwayo 1994) and spread to the open water as they grow. Ogari (1984) observed in the Nyanza Gulf of the lake, a tendency for the size of the fish to increase with increasing depth. It is a fast growing species reaching maturity at the age of three to four years (Ogutu-Ohwayo 1994), and TL between 50 cm (males) and 84 cm (females).

Juvenile Nile perch feed on invertebrates, mainly crustacean prawn (*Caridina nilotica*), but show ontogenetic shifts in diet with age. Adults are predominantly piscivorous feeding mainly on haplochromine cichlids and the native pelagic cyprinid, *Rastrineobola argentea*. With the reduction in the haplochromine components of the perch diet in the lake, there is growing concern of cannibalism that might contribute to the reduction of the juvenile populations. This seems at least partly countered by the high fecundity (adult females produce about 140 eggs per gram of body mass) of Nile perch (Ogutu-Ohwayo 1984, Schindler *et al*. 1998). Breeding occurs throughout the year but there are two peak breeding periods during the long rainy season (March – May) and the short rainy season (September – November). Two recruitment periods are observed per year, the main one occurring between September and January and a minor one in June (Rabour 2003).

1.6 Evolution of Nile perch fishery

Nile perch was introduced in Lake Victoria from lakes Albert and Turkana (Ogutu-Ohwayo 1990) in 1960 to boost fisheries production following the collapse of the native fishery. Prior to this, Lake Victoria had a very diverse fish fauna comprising 28 genera (Greenwood 1974) with approximately 500 species. Over 90% of these species were haplochromines cichlids (Greenwood 1974, Van Oijen *et al*. 1982, Witte *et al*. 1992). During this period the native gill net fishery was based on two native tilapiine cichlids, *Oreochromis variabilis* and *Oreochromis esculentus* (Graham 1929). These fish were overexploited due to intensive fishing pressure following the introduction of efficient nylon gill nets and outboard engines. As a result their fisheries collapsed over time (Kudhongania and Cordone 1974). Consequently, under the colonial government four exotic tilapiine species, *Tilapia melanopleura, Tilapia zillii, Oreochromis leucostictus* and *Oreochromis niloticus,* were introduced to the lake in the 1950s (Welcomme 1968). Later in the 1960s Nile perch was also introduced. Of all the introduced species, two species: *O. niloticus* and *L. niloticus* succeeded and have since then expanded their stocks to the extent that they now dominate the fisheries of Lake Victoria. The two species have, however, segregated their habitats with Nile tilapia occupying the shallow (< 15 m deep) areas while Nile perch occupies virtually the whole pelagic zone in areas up to 60 m deep. The result is that the two species suffer different fishing mortalities.

The introduction of Nile perch in Lake Victoria led to a change from the original subsistence fishing to commercial-oriented fishing targeting the introduced species (Muhoozi 2002). The introduction of Nile perch greatly improved annual landings from the lake. During the period preceding introduction, annual fisheries production from the whole of Lake Victoria based on the native multi-species stocks was about 100,000 tons which translated into a four to fivefold increase to over 400,000 tons year^{-1} in the late 1980s (Muhoozi 2002), with the introduced Nile perch and Nile tilapia dominating the catches. This resulted in a substantial fishery based on Lake Victoria supplying exports worth an estimated US$300 million to the three bordering countries, Tanzania, Kenya and Uganda (Lake Victoria Fisheries Organization (LVFO 2004)). This provided a major source of revenue for fisher folk, processors and exporters. It is worthy noting that in recent years the total contribution to annual catches of Nile perch have continued to reduce despite increasing fishing effort (Muhoozi 2002). Therefore, the proportional contribution of Nile tilapia and Dagaa (*Rastrineobola argentea*) have continued to increase.

Muhoozi (2002) explained that boat size and propulsion power determines the distance offshore in which the boat operates, the type and size of gear employed, and consequently the type and size of fish harvested. He observed that gillnets less than 127 mm (minimum allowable size) stretched mesh size constituted 53 and 23% of nets in parachute and paddled Sesse boats (small boats that operate in inshore areas) but only 1.9% in motorized boats (that operate in deep waters). Results from the frame survey indicate that illegal gears have increased considerably in recent years, especially beach seines operated inshore and indiscriminately catch juvenile fish. These changes in fishing effort of juveniles are coupled with declining catch per unit of effort and are considered indicators of declining stock density, suggesting that the current fishing effort is not sustainable (Muhoozi 2002). Lake Victoria Fisheries Organization (LVFO) reported a 20% increase in fishing vessels on the lake from 42,483 to 52, 479 in a period of only two years 2000 – 2002 (LVFO Frame survey results 2002).

The elastic increase in the overall fishing effort, reduction in the catch per unit effort, and constant reduction in the gear sizes have culminated in over exploitation of juvenile Nile perch. There have been constant reports in the media of authorities impounding enormous quantities of juvenile fish for example “The New Vision” of August 17th 2004, reported Ugandan authorities impounding immature fish worth Uganda Shs. 70 million. In order to control juvenile fishing and protect adult spawning stock, the East African Council of Ministers under the auspices of LVFO adopted the slot size for Nile perch, allowing only fish between 50 and 85 cm TL to be caught and landed in all the three East African countries.

Over-fishing in Lake Victoria has been an important consequence of the open access nature of the fishery. Fisheries management options world over are emphasizing property rights over the fisheries that not only restrict the total output from the fisheries but also enhance collective responsibility. However, capture fisheries of Lake Victoria and similar developing world aquatic systems have remained largely open access. Control measures have hitherto targeted limiting gear types and mesh sizes but the overall fishing factors have continuously increased. Even the gear restrictions imposed have been largely ineffective due to difficulty in surveillance and monitoring.

1.7 Objectives of the study

The overall objective of this study is to evaluate the Nile perch stocks and fishery exploitation patterns in the Ugandan part of Lake Victoria. This was achieved through performing the tasks outlined below

1.7.1 Tasks

- Survey published literature on biological parameters (growth, maturity, length-weight and mortality) of Nile perch in Lake Victoria.
- Analyze the trends in the Nile perch fishery since its inception.
- Analyze survey methods used in Nile perch stock assessment, estimate stock size indices, notice deficiencies and suggest possible improvements.
- Generate catch-effort information from catch assessment survey data.
- Analyze available data and together with information from literature, develop a yield per recruit analysis and attempt to estimate current fishing mortality.

2 LITERATURE REVIEW

2.1 Growth and mortality of Nile perch

Since its introduction into Lake Victoria, Nile perch growth parameters have been estimated by various authors using different methods. Acere (1985) estimated the von Bertalanfy growth parameters L_∞ and growth rate K as 251 and 0.09/year respectively from the Ugandan waters of the lake using a probability paper method. The same parameters were estimated in the Nyanza gulf in 1987 using Bhattacharya (1967) analysis and Gulland and Holt (1956) plots as $L_\infty = 205$ and K = 0.19 (Asila and Ogari 1988). The same parameters had been estimated from Lake Chad (native habitat for Nile perch) using data from scale readings for the first five years as $L_\infty = 93$ and K = 0.29 (Hopson 1972). This indicated that Nile perch was growing fast and reaching a large size at infinity in the new habitat (Lake Victoria). Recently, Rabour *et al*. (2003) using beach seine and hook and long-line samples estimated L_∞ = 169 and 230 and K = 0.18/year and 0.195/year respectively from the Nyanza Gulf (Kenya). Muhoozi (2002), using catch curve superimposed on structured length frequency samples, estimated $L_\infty = 221$ and K = 0.17/year.

Growth parameters of Nile perch in Lake Victoria seem to have been fairly constant since its introduction. The minor differences observed are likely to be largely a function of the methods applied and samples used. Rabour *et al*. (2003) explained the difference in L_∞ and K values obtained from the beach seine and hook and line fisheries on the basis of different habitats occupied by the two stocks and their feeding habits. Beach seines samples were from stocks living in the littoral areas while hook and line samples were from a stock living in the open and deep waters. These two different stocks tend to show different feeding habits (Rabour *et al*. 2003, Wandera *et al.* 2003). What has greatly changed however, is the total mortality (Z) influenced by constant change in fishing mortality (F). Asila and Ogari (1988), using data collected from 1978 to 1984, obtained values of Z that ranged from 2.2 (1978-79) to 1.3 (1982-84) with an average of 1.6 over the seven year period. Similarly, Acere (1985) estimated Z values that decreased from 2.6 to 0.85 between 1964 and 1977. These two studies were carried out during the Nile perch boom where the turnover increased with years and declined later (Rabour 2003).

Recent estimates put Z values at 0.724/year and 0.975/year for beach seine and line fisheries (Rabour *et al.* 2003) but with a high exploitation rate (E) of 0.486 and 0.663 respectively. In the Ugandan section of the lake, Muhoozi (2002) estimated Z = 1.88yr^{-1} and E = 0.86. With Natural mortality estimated at 0.30 in the same study (Muhoozi 2002), it follows that fishing mortality is estimated to be exceedingly high. The observed difference might also be purely explained by the different selectivity of the sampling gears used and the different components of the stocks sampled.

Biological parameters of Nile perch seem to have continued to change and are probably still changing since its introduction into Lake Victoria. For example, in around 1984 the size at 50% maturity was 74 cm and 102 cm for males and females respectively (Asila and Ogari 1988). A decade later they were reported to mature at 60 cm and 90 cm for males and females respectively (Ogutu-Ohwayo 1994). In 2001 the same parameters were 55 cm and 75 cm TL for male and females respectively (UNECIA 2002). A recent survey in the Ugandan part of the lake (Wandera *et al*. 2003) put size at maturity at 56 cm and 70 cm TL for males and females respectively. The overall sex ratios in Nile perch are about 30 females per 100 males (Wandera *et al*. 2003), indicating a male dominated population. Sex ratios, however, change across the size ranges of fish. Juveniles are male dominated with ratios ranging from three to eight males for one female amongst Nile perch up to 39 cm TL, the ratios of males to females are between two and one for fish between 40 – 70 cm TL. Beyond this size females dominate (Wandera *et al*. 2003).

2.2 Trends in Nile perch fishery

The East African Freshwater Fisheries Research Organization (EAFFRO) in collaboration with UNDP/FAO carried out fish stock surveys of Lake Victoria between 1969 and 1977. A comparison of 1976-77 trawl catches from the Nyanza Gulf (Kenya) with records from 1969-70 indicated a reduction in stocks of species of commercial importance (*Tilapiines*, *Ningu Labeo victorianus* and some *Burbus* species). *Mormyrids* and *Schilbe mystus* were virtually absent (Ogari 1985). Abundant species caught then were haplochromines and dagaa (*Rastrineobola argentea*) accounting for 34.1% and 30.3% respectively of the commercial landings in 1976. At this time Nile perch was not established in the new habitat and contributed only 0.5% (Ogutu-Ohwayo 1990).

Following the reduction in large commercial species, fishing effort was directed to small haplochromines and dagaa. Gill nets of mesh sizes 38 – 46 mm (1.5 – 1.8 inches) were introduced to harvest haplochromines and a mosquito seine of 10 mm (0.4 inches) for dagaa. At this time two of the introduced species Nile perch and Nile tilapia were slowly establishing themselves and eventually came to dominate landings in the mid 1980s (Ogutu-Ohwayo 1990, Kitchell *et al.* 1997). With increased catches, fishers voluntarily shifted to larger mesh sizes targeting large Nile perch that was then dominant in the lake (Ogutu-Ohwayo 1990, Muhoozi 2002).

Large fish were quickly over-fished and fishers reversed mesh sizes. For example, in 1989, 45% of the gill nets used in the Nile perch fishery were 203 mm but by 2000 it was only 2.7% (Katurole and Wadanya 2001). The result is continued harvesting of small fish as demonstrated by the amount off juvenile Nile perch that is constantly landed all over the lake (Lake Victoria Fisheries Research Project Phase II (LVFRP/TECH/01/16)).
Fishing effort has been rising while catches are showing decline, suggesting that maximum sustainable yields could have been exceeded and the fishery is moving to a state of stock depletion (Katurole and Wadanya 2001). As things stand, there is a serious risk that important fisheries based on Nile perch and Nile tilapia will collapse unless urgent action is taken to improve their management.

The Lake Victoria Fisheries Research Project conducted six lake-wide hydro acoustic surveys in the years 1999-2002, which were done at six-month intervals to study seasonal differences. In this case the results showed a declining biomass index, with the total for all species crashing from 2.1 to 1.5 million tons over the period August 1999 to August

2002 (Lake Victoria Fisheries Research Project Phase II (LVFRP/TECH/01/16)). Most of the reduction was in the Nile perch index, down from 1.7 to 0.7 million tons over the same period. On the other hand, the stocks of small pelagic fish appeared to be relatively stable at around 570,000 tons for *R. argentea* and haplochromines combined. It is therefore likely that the continued reduction in population of Nile perch may result in the recovery of the other species (Witte *et al.* 2000), which are unfortunately of low commercial importance compared to Nile perch.

2.3 The over-fishing problem

Infrastructural development has played a big role in increasing exploitation and consequent over-fishing in Lake Victoria. Prior to fish introductions, native fisheries of the lake were exploited using small manually propelled rafts and simple dugout canoes using local materials such as papyrus seine nets, basket traps, harpoons and hooks (Graham 1929, Muhoozi 2002). These types of crafts were relatively inefficient and could not go a long distance from shore. Therefore, they had little impact on fish stocks (Muhoozi 2002). With the introduction of nylon gill nets and outboard engines, efficiency in exploitation and offshore fishing increased and thus the fishery based on the two native tilapiines (*O. esculentus* and *O. variabilis*) collapsed. The decline in the stocks of the native fish is estimated to have occurred at the time when the railway construction reached the shores of the lake, better roads, and the mushrooming of urban centres. This both increased the population of the Lake Victoria hinterland, which provided a market for the fish, and opened the possibility of fish markets far from the immediate lake catchments.

Catch recording is difficult given the disperse nature of the fishery and landings. By 1994, official statistics from the three countries showed that landings were around 363,000 tons in 1994, with 29% landed in Kenya, 27% in Uganda and 44% in Tanzania. This was an enormous increase from less than 100,000 tons a decade earlier in 1984, when Nile perch was just beginning to be significant in the catches. Fishing effort seems to have followed similar trends, for example Muhoozi (2002) indicates that during the period when Nile perch was establishing itself in the lake, fishing boats on the Ugandan part of the lake increased at a very low rate. From 1970 to 1988 the number of fishing boats had only increased by 827 from 2643 to 3470, but increased tremendously to 8000 in 1990 and 15,462 in 2000. Two years later, the frame survey put the number of fishing boats on the Ugandan part of the lake at 18,612. It is suggested that the initial increase in fishing crafts observed in the last decade of the 20th century was due to improved catches of the introduced species in the lake (Muhoozi 2002).

Rabour *et al.* 2003 recommended further investigations to monitor the demographic evolution of the Nile perch fishery and warned of possible over-fishing. Despite difficulty in getting sensible age readings from tropical fish, better methods of stock and population dynamics need to be urgently undertaken. Length based methods of studies in fish population dynamics in tropical regions are increasingly becoming important due to difficulty in obtaining sensible age readings from hard parts (Sparre and Venema 1998). Regardless of the method used, seasonality needs to be taken into account in fish population studies. In the tropics there are four seasons; the long rainy season (March – June), the short dry period (July-August), the short rains (September – November), and the long dry season (December – February). With the recent global climatic changes, however, these seasons tend to overlap a lot and are therefore not so distinct.

Biologists have warned that the export fishery could collapse completely within a few years. It looks increasingly as though the Nile perch and Nile tilapia will prove a short-lived bonanza for the commercial fishing industry, trading the lake's biodiversity and an important local food source for a significant, although perhaps unsustainable, source of export earnings. Trends in the annual catch yield are falling despite increasing effort, an indication of a declining fishery (Katurole and Wadanya 2001, Muhoozi 2002). All these warnings point to one thing, i.e. that the fisheries of Lake Victoria may again collapse. If urgent review is not undertaken in the fishery sub-sector, a repeat of the collapse is imminent. As the saying goes, it is a not a mistake to make a mistake, but it is indeed a terrible mistake to repeat a mistake.

3 MATERIALS AND METHODS

3.1 Study area

The study focused on fishing activities within the 43% area of Lake Victoria making up Uganda's portion of the Lake (Figure 1). In this part of the lake the mean depth is 40 m and the deepest zone ranges from 60 – 80 m. The Ugandan part of the lake contains a large number of islands occupying about 3.7% that provide ideal areas for fishing villages. This feature has attracted many fishers to settle and concentrate on exploiting the fishery resources in the islands. Over a dozen fish processing factories have been set up along the 1750 km stretch of Ugandan coastline in the surrounding districts which provide a ready market for fish and thus increasing the demand.

3.2 Available data

Frame survey data (2000 and 2002), Catch Assessment Survey (CAS) data (2003), and Trawl survey data (1997– 2001, 2003/2004) were used in this study.

3.2.1 Frame survey data

Frame surveys are carried out on Lake Victoria to determine the overall fishing factors operating on the lake. The spatial and temporal distribution of fishing effort is evaluated as well as the structure and function of the fleet. Frame surveys were conducted in 2000 and 2002 under the auspices of the EU funded Lake Victoria Fisheries Research Project (LVFRP), and the Lake Victoria Fisheries Organization (LVFO) and have since been posted on the LVFO website (www.lvfo.org). From the data collected, the overall fishing fleet, the number of fishers targeting Nile perch, the types and numbers of gears involved, and the proportion of each type of gear are evaluated.

3.2.2 Trawl survey data

Between 1999 and 2001 trawl surveys were conducted by scientists from the Fisheries Resources Research Institute (FIRRI), under LVFRP and the Implementation of Fisheries Management Plan Project (IFMP) coordinated by LVFO to determine population characteristics of the commercial fish species in Lake Victoria. The Ugandan portion of the lake was divided into three zones. Sampling in the zones was done in turns, with one zone sampled per month for a period of 10 days. On some occasions, however, more than one zone was sampled in one month. Each zone was divided into stations measuring 5 x 5 nautical miles. Each station trawled for 30 min at an average speed of 3 nm hr^{-1}. A total number of 836 hauls were recorded for the period 1997-2001. Here, the results of this survey are analysed, deficiencies in the methods of sampling pointed out, and possible improvements considered. In 2003, the IFMP started a new monitoring program which is expected to be conducted for five years. In the new program the size of the stations were increased to 15 by 15 nautical miles and all the zones are to be covered.

3.2.3 Catch Assessment Survey (CAS) data

Data from the operating fishing fleet were collected by scientists at the Fisheries Resources Research Institute (FIRRI) in 2000-01 and 2003. It was also carried out in the three zones of the lake where trawl surveys were carried out. At a fish landing site, boats were randomly selected as they landed, the size and type of boat was taken down, its catch assessed and one of the crew members interviewed on the target species, mode of fishing operation, number of gears used and frequency of operation. Data collected include: length measurements by gear and catch per unit effort for each gear.

3.3 Methods

3.3.1 Biological parameters

Published information was surveyed to obtain growth parameters (L_∞ and growth coefficient K), size and age at maturity and condition factor (from length-weight relationship). These values were compared with those determined using available data in this report.

3.3.2 Analysis of trawl surveys

From the trawl surveys, length-weight relationship, size at sexual maturity, and length frequency distribution of Nile perch were analysed. Catch rates from various zones and stations and trends were evaluated in space and time. The overall survey design was evaluated in relation to the results.

3.3.3 Analysis of CAS data

Catch per unit effort (CPUE) of each type of gear and proportion of total landings landed by each gear were evaluated. Length frequency distributions of Nile perch from the different gear types of commercial fishers generated from CAS was fitted onto the logistic selection curve in FISAT and used to evaluate selection patterns of the different gears.

3.3.4 Evaluation of yield per recruit

Using information generated from available data and some established parameters from literature, yield per recruit and spawning stock biomass per recruit analyses were undertaken through the following:

a) Estimation of length and weight at age

Length frequency distributions from trawl surveys were fitted to the von Bertalanffy growth function using published length at infinity and estimated growth constant K, using K scan in FISAT. Using L_∞ from literature and K determined in this study, changes in fish length with time were estimated using the model below.

$L_{t+\Delta t} = L_t + [L_\infty - L_t][1-e^{-k\Delta t}]$ ....equation (1)

Mean length at age estimates were then converted to mean weight at age using the length weight relationship:

$w = a L^b$ ....equation (2)

b) Proportion mature at length/age

Proportions mature at age/length were then determined using size at sexual maturity obtained from a logistic maturation model given below:

$Y_L = 1/(1+e^{-(\alpha+\beta L)})$..........................equation (3)

where Y_L is the proportion mature at length L and α and β are constants.

c) Estimation of mortality

Using length converted catch curve analysis in FISAT, total mortality Z was estimated from the length frequency distribution of fish from all the gears used in the Nile perch fishery in the Ugandan part of the lake recorded during CAS survey according to the equation below:

$Ln(N_i/\Delta t_i) = a + b \cdot t_i$ …………………..Equation (4)

where N_i is the number of fish in length class "i", Δt is the time needed for the fish to grow through length class "i", t is the relative age computed with $t_o = 0$, and b with sign changed is an estimate of Z.

Using L_∞ and K, with mean water temperature, natural mortality M was computed according to Pauly's equation:

$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$…………Equation (5)

Fishing mortality F was then evaluated by subtracting natural mortality (M) from total mortality (Z), from the empirical formula:

$Z = M+F$, …………………..Equation (6)

The exploitation ratio (E) was then determined from the formula:

$E = F/Z$…………………..Equation (7)

d) Gear selectivity

Catch curve analysis was then extrapolated to estimate probabilities of capture by each gear through backward projection of the numbers that would be expected if no selectivity by the gear had taken place, using:

$N_{i-1}' = N'_i \cdot Exp(Z\Delta t)$ …………………..Equation (8)

The extrapolated points were used to estimate the selection parameters for each gear, which were used in yield per recruit analysis of the particular gear.

e) Yield per recruit analysis

Yield per recruit analysis was done using the parameters determined in sections a) – d) above in an Excel spreadsheet.

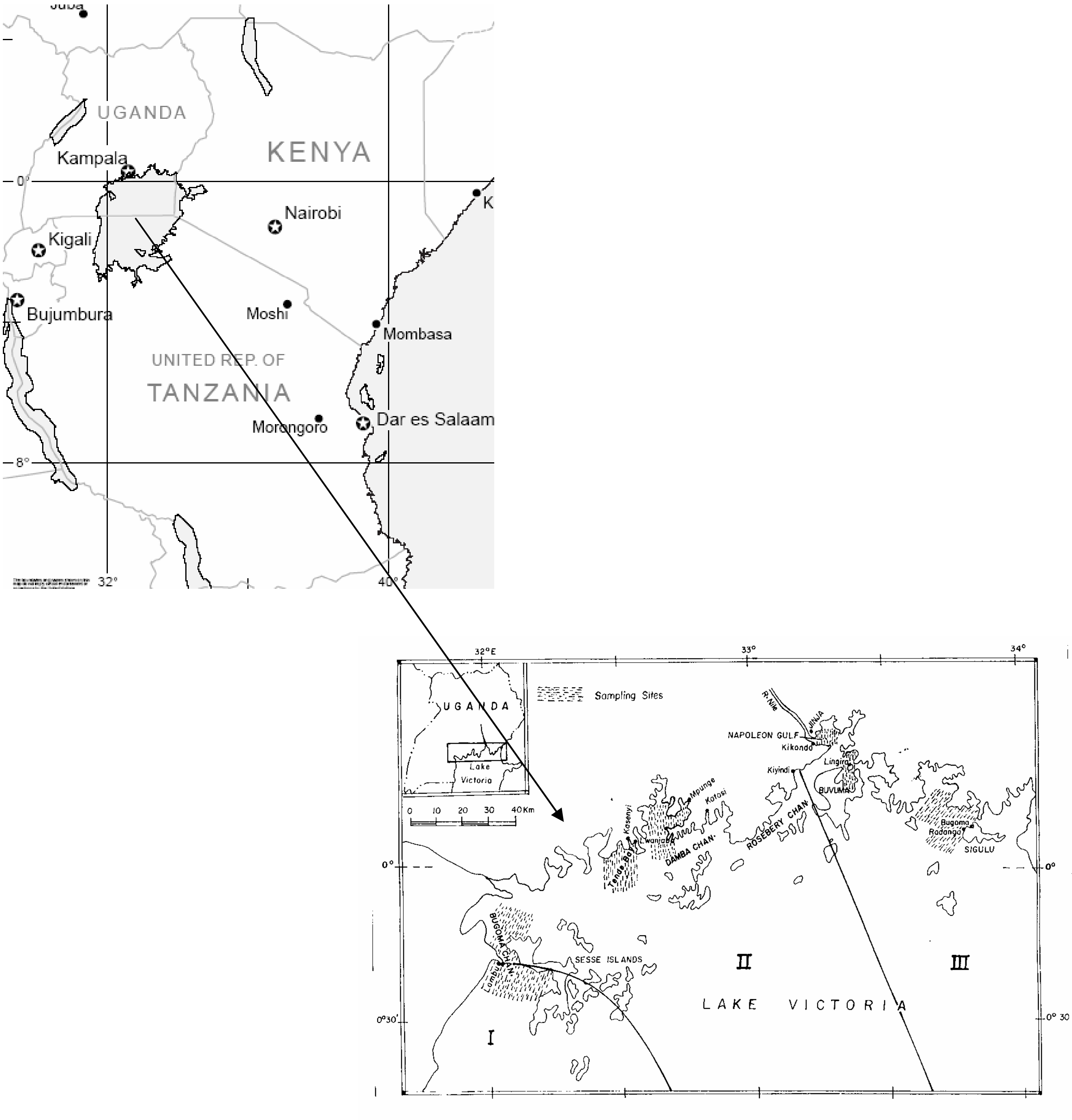


Figure 1: Map of Lake Victoria, Uganda showing the three zones sampled.

4 RESULTS

4.1 Trawl surveys (1997 – 2001)

4.1.1 Survey design

LVFRP during its second phase (1997 -2001) set out to conduct surveys of the status of the fish stocks and fisheries of Lake Victoria. The objective was to propose prospects for maintaining catches that are sustainable. Different kinds of surveys were used. The research vessels were used to conduct fishing surveys using bottom trawls. Gill net surveys were conducted in shallow areas not fit for trawling using small canoes. Trawls were conducted in shallow areas (10- 50 m deep) of the lake, while lake-wide hydro acoustic surveys were used to monitor the whole water column. Each of the three East African States' National Research Institutions carried out individual monthly bottom trawl surveys using their research vessels. While hydro acoustic surveys were conducted jointly using the Tanzanian Fisheries Research Institute's modern research vessel, the Victoria Explorer (constructed by LVFRP), at six months intervals.

On the Ugandan part of the lake, using the Institutional Research Vessel (Ibis), bottom trawl surveys were conducted at monthly intervals in the three years up to September 2000. A total of 836 hauls were taken during this period. Additional quarterly surveys were conducted in December 2000 and March 2001. The catches of Nile perch obtained were used to calculate an abundance index for this species. For the purpose of this survey, the Ugandan part of the lake was divided into three zones I, II and III (Okaronon *et al.* 1999). Zone I (Western zone) runs from the Uganda/Tanzania boarder to Bugoma Channel (Bukakata) up to the River Katonga. Zone II (Central zone) is from the River Katonga to Rosebery channel (Kiyindi) and Zone III (Eastern zone) is from the Rosebery channel to the Uganda/Kenya border (Figure 1).

The sampling area was divided by grids into square stations (popularly known as "boxes") measuring 5 X 5 nautical miles. Sampling was done for a period of 10 days per month in one zone and whenever possible each station trawled at least once. Due to logistical constraints, all zones could not be sampled in one month and were therefore sampled in turn. Sampling was only done in the day time between 7.30 am and 6.30 pm. Samples were obtained by bottom trawling using a trawl net with a cod end mesh size of 25.4 mm and trawled at the constant speed of 3.4 knots for 30 minutes. GPS positions and depth were recorded at the start and end of each trawl. However, in some cases the GPS was either faulty or missing and therefore GPS positions were not recorded.

4.1.2 Sample treatment

After hauling, the fishes caught were sorted according to species and total numbers and total weight determined for each species. Length measurements and examination of biological parameters was done for the two species of commercial importance (Nile perch and Nile tilapia). In cases where all the fish in a single haul could not be measured sub-samples were taken. In such cases all big Nile perch that could bias sub-sampling were first selected out and measured and weighed individually. The total weight of the remaining small fish was then obtained and a sub-sample of those measured individually. The total weight of the sample was then used to compute the overall frequency distribution from the proportion of each length group in the sub-sample. The fish biology and ecology team on the crew would then proceed to take the biological information (sex, maturity, food and feeding etc) of the fish.

4.1.3 Length frequency distributions

Length frequency distributions of Nile perch from the bottom trawl surveys of the Ugandan part of the lake are illustrated in Figures 2 and 3. While Nile perch is known to grow up to almost 200 cm, and mature above 50 cm TL., length frequency distributions of the fish from the monthly trawl samples indicate that more than 90% are below 50 cm TL (Figures 2 and 3). Modal frequency occurs around 10 cm throughout all the months suggesting continuous spawning, however, bimodal peaks in length frequency plots occur around April and September which coincide roughly with the periods of long and short rains respectively indicating possible peak spawning periods around these months (Figures 2 and 3).

Various publications indicate that the length at infinity of Nile perch in Lake Victoria lies above 200 cm (Section 2.1). However, Rabour *et al.* (2003), using samples from beach seine fishery (with a similar form of selection curve as the bottom trawl used in this study), obtained an L infinity of 169 and a growth constant K = 0.18yr^{-1}. Using a direct fit of the von Berntalanffy growth function to length data from the monthly trawl surveys for the periods 1998/99 and 1999/2000 with L infinity fixed at (169) in FAO-ICLARM Stock Assessment Tools (FISAT) using the Electronic Length frequency Analysis (ELEFAN) I, gave a K value of 0.17 for 1998/99 and 0.18 for 1999/2000 periods. These values closely correspond to those obtained by Rabour (2003) using beach seine samples from the Nyanza gulf in Kenya and Muhoozi (2002) using catch data from the Ugandan section of the lake (see section 2.1). A fit of the VBGF onto length frequency distribution over this period (Figure 4) indicates that the cohorts disappear just after two years of growth, yet *L. niloticus* is a long lived species (over 10 years). Given the available data, which cover a narrow range of the expected length distribution, it was considered inappropriate to try to estimate L infinity with a high degree of precision but rather values reported in literature were used for further analysis in this report.

A VBGF plot indicates continuous recruitment with two cohorts coming into the population within a one year period implying biannual peak recruitment in the Nile perch fishery (Figure 3).

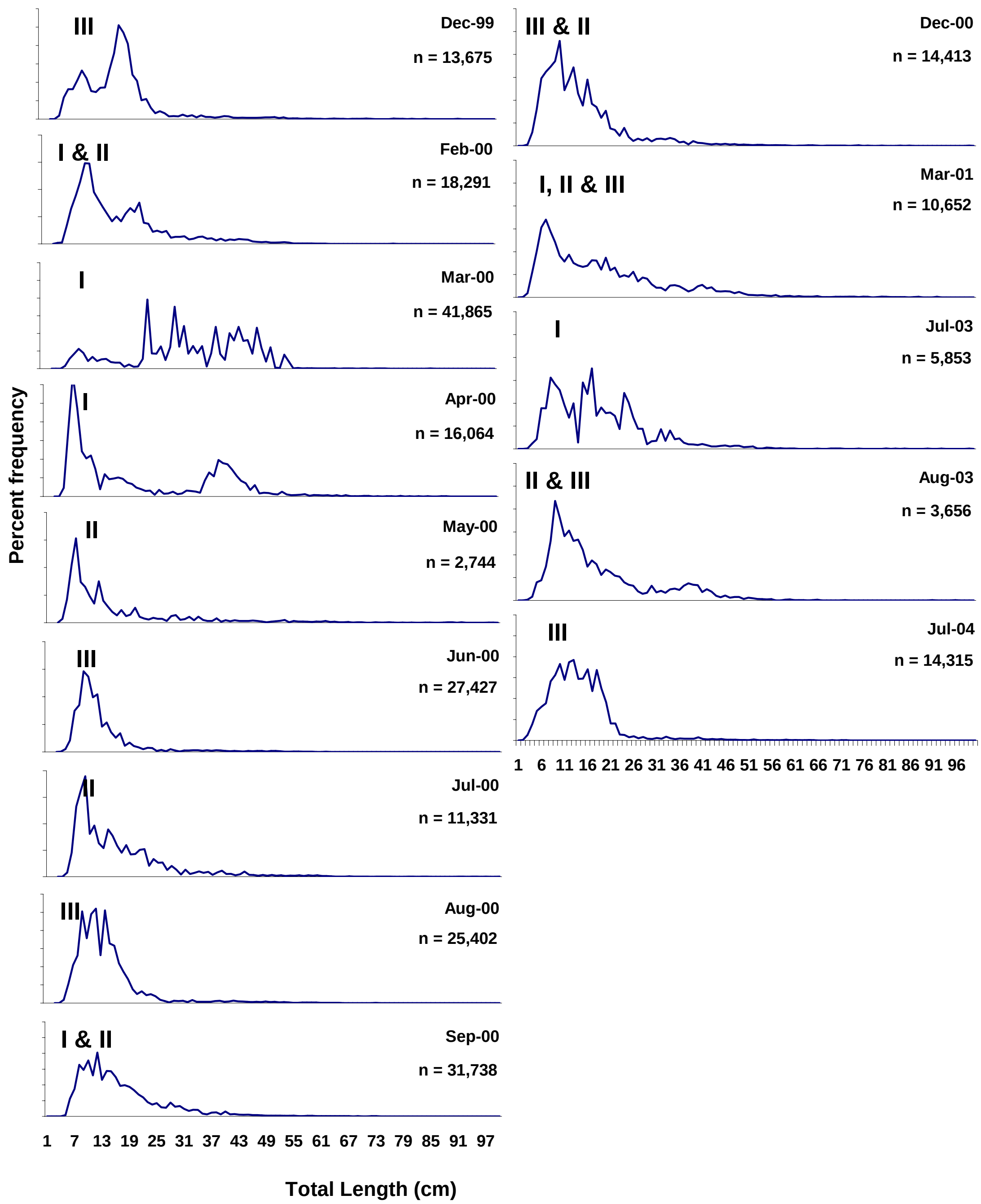


Figure 2: Length frequency distribution of Nile perch from monthly bottom trawl surveys for the period December 99 to September 00 and quarterly surveys December 00, March 01, July/August 03 and July 04 (zones I, II, & III are sampled).

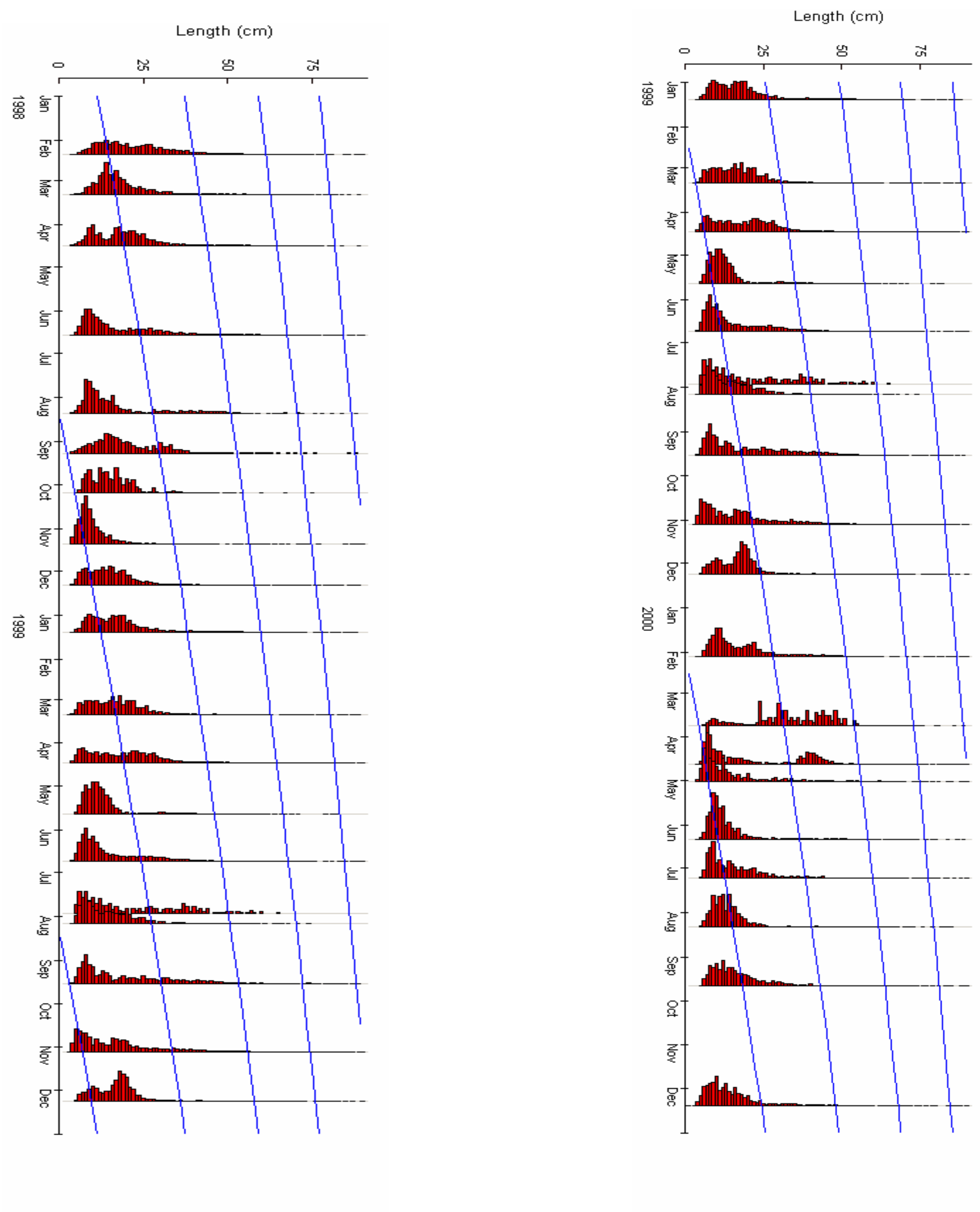


Figure 3: The von Bertalanaffy growth function fitted on length frequency distributions of Nile perch obtained in trawl surveys between 1998 and 2000.

4.1.4 Recruitment

Using FISAT, monthly recruitment to the survey was calculated as a percentage using monthly length frequency distributions from the trawl survey data. Results indicate continuous recruitment throughout the year with two peak periods. A strong recruitment pulse was observed between February and June (up to 15% recruitment) and August to October (about 10% recruitment) (Figure 4). The modal length of the juvenile fish (around 10 cm TL) (Figures 2 and 3) could suggest that they appear in the trawl catches when they are about half a year old (from VBGF, the fish reaches the age of one year between 17 – 24 cm TL). This would therefore suggest that the strong pulse appearing in the first period of the year could represent those hatched during the second pulse period and vice versa. These periods are close to those indicated in Figure 2. Both of these periods are around the rainy seasons suggesting a close link between these seasons and peak breeding.

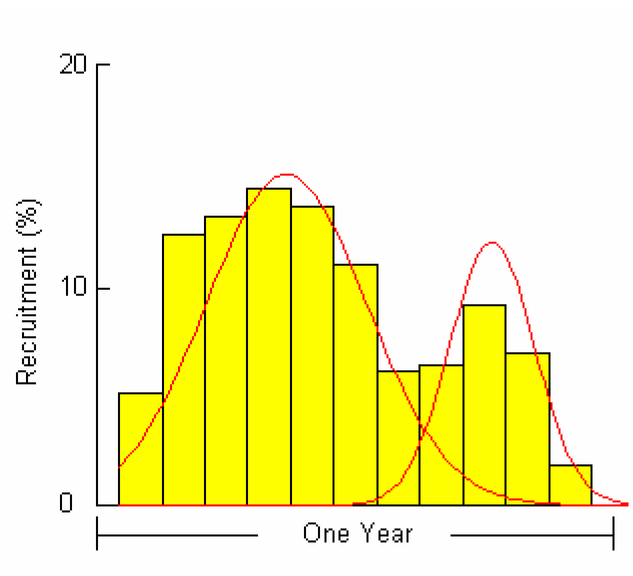


Figure 4: Recruitment patterns into the Nile perch fishery in Lake Victoria Uganda (adapted from FISAT).

4.1.5 Length – weight relationship

Length – weight parameters "a" and "b" in the length- weight relationship, $W = aL^b$, were estimated using data from the trawl surveys. A direct length-weight plot in an Excel spreadsheet using the power function produced Figure 6a. The data fit quite well as the model for fish less than 70 cm TL (Figure 6b). But either due to relatively few data points or non-isometric growth, the model seems to underestimate the weight at lengths greater than 70 cm (Figure 6a). The log transformed model (Figure 6b) produces a linear equation for easy estimation of length-weight parameters. The values of parameters "a" and "b" (0.0177 and 2.9082 respectively) obtained from the direct fit and log transformed models did not vary.

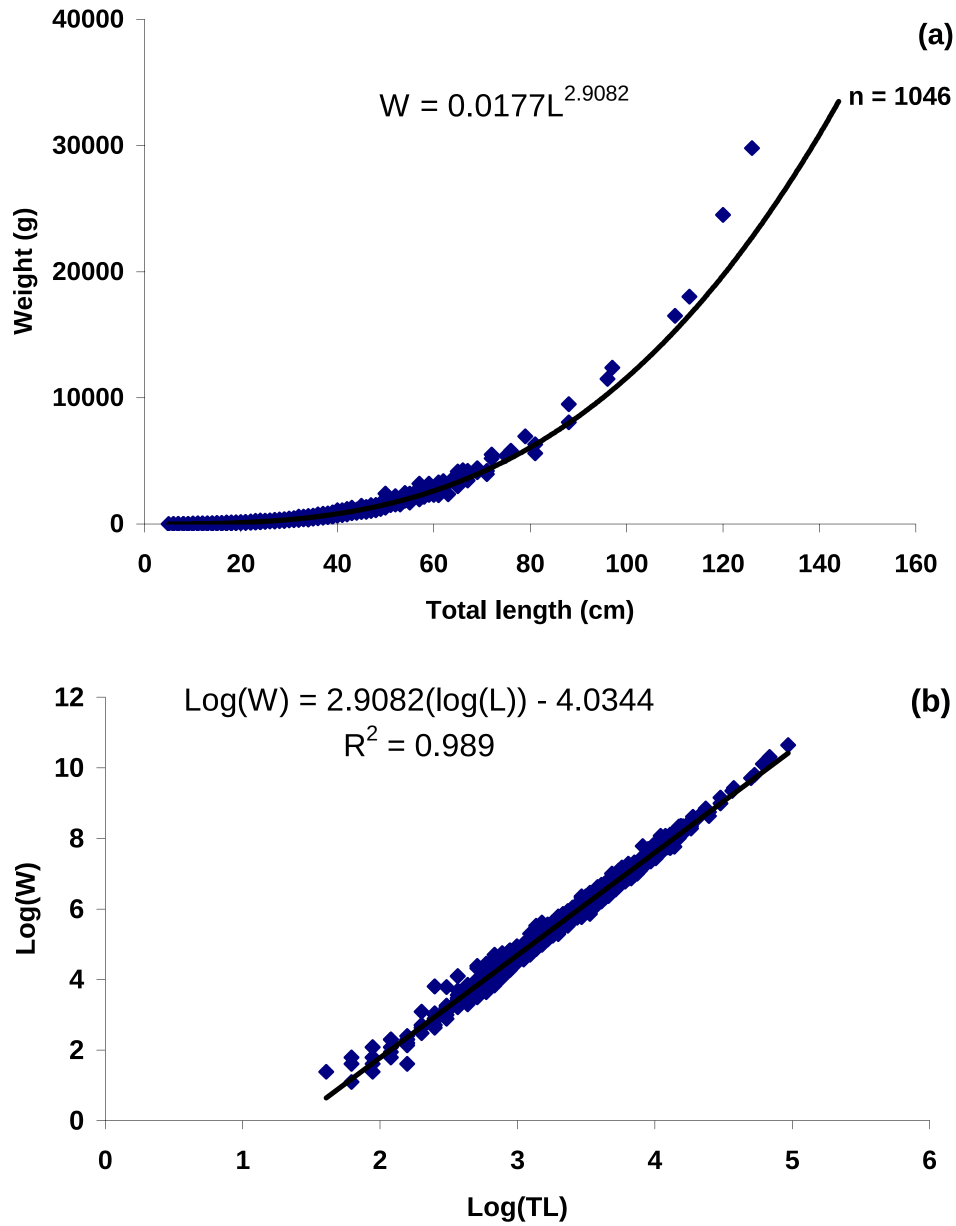


Figure 5: Length weight relatioship of *L. niloticus* from Lake Victoria, Uganda a). Direct weight length fit and log transformed b).

4.1.6 Size at sexual maturity

By fitting a logistic maturation curve on length and maturity data from the trawl survey using Solver in an Excel spreadsheet, the size at 50% maturity (size at sexual maturity) of Nile perch was estimated from the curve to be 56 and 70 cm TL for males and females respectively (Figure 6). Combined data gave an average size at sexual maturity of 59 cm, a figure closer to that of males probably because there are more males than females in the samples used. The size at 50% maturity obtained in this study is lower than most of those reported in literature (section 2.1), which describes a decreasing trend in size of sexual maturity of Nile perch in Lake Victoria. The results here show a further decrease in size at sexual maturity, a condition closely associated to a stressed fishery probably due to overexploitation. Males have continued to dominate in the smaller sizes up to 50 cm TL (two females in five males), between 50 and 80 cm TL the sex ratios are almost one to one, but females dominate in sizes beyond 80 cm.

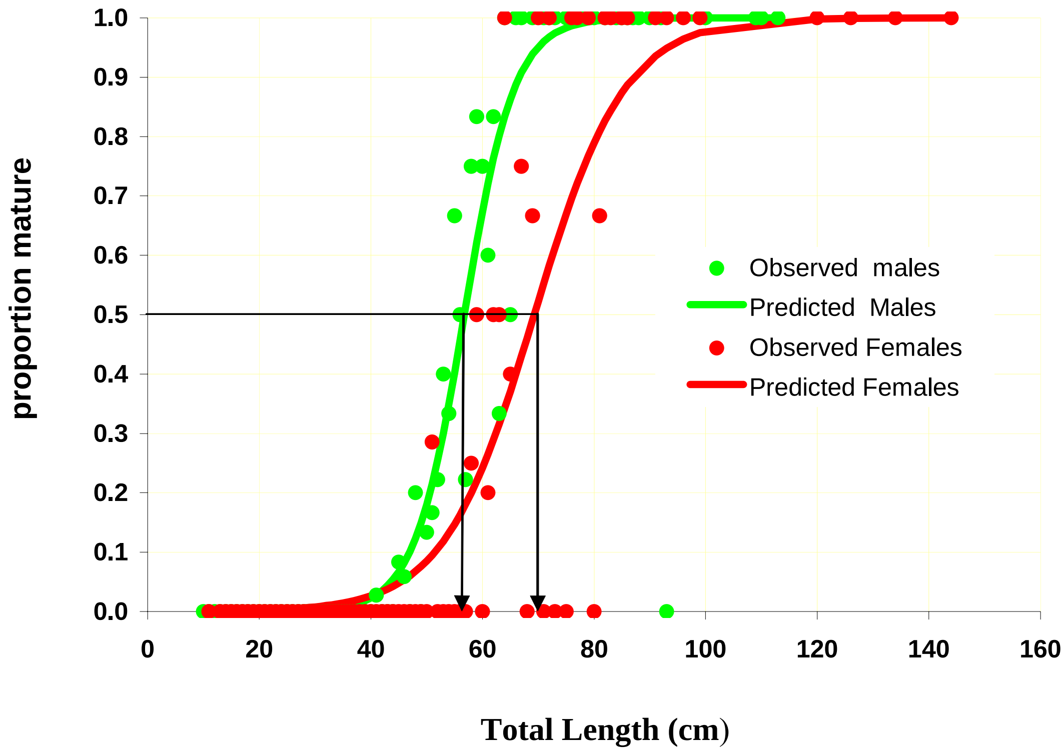


Figure 6: Size at sexual maturity of Nile perch from Lake Victoria Uganda.

4.1.7 Catch characteristics

Catch rates of Nile perch (measured in kg/30 minute – haul) were calculated from trawl surveys. The distribution of catch rates on the Ugandan portion of Lake Victoria, as observed in the trawl surveys 1997-2001, is illustrated in Figure 7. Catch rates of the Western and Eastern zones appear higher than in the Central zone. Sampling stations are concentrated in the near shore areas of the lake. Catch rates plotted on the map show smaller circles (lower catch rates) dominating towards the offshore deeper zones of the lake. Stations where no fish was recorded (represented on the map by "+") are more frequent towards the deeper zones of the lake (Figure 7). The proportion of zero hauls (hauls that recorded no fish) by depth were found to be unequal ($\chi^2 = 85$, df = 5, P=0).

Whereas the deepest stratum sampled (50 – 60 m) had 50% of the hauls with no catch, the shallow stratum (0 -10 m) had only 1% of the hauls without fish.

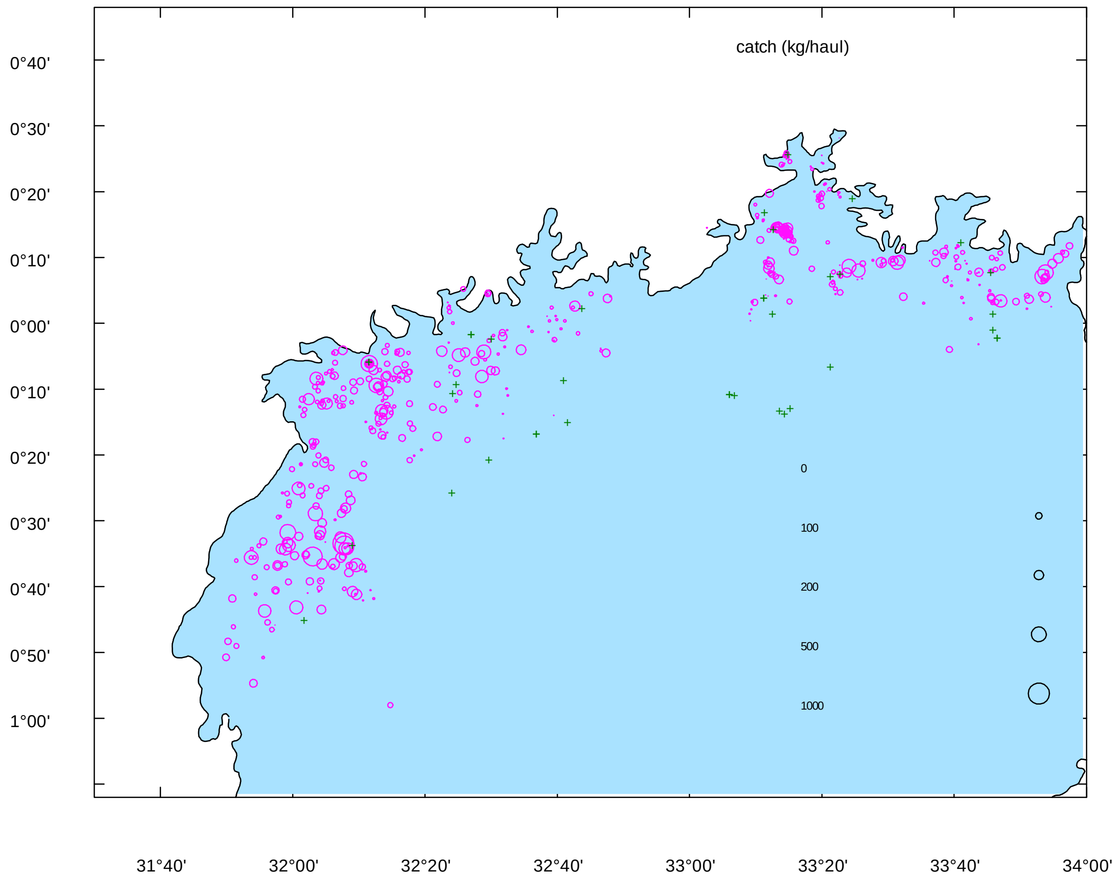


Figure 7: Distribution of sampling stations and catch rates of Nile perch in the Ugandan part of Lake Victoria ("+" represents hauls in which no fish was recorded).

The relationship between water depth and Nile perch abundance becomes clearer in Figure 8. Whereas median catch rates by weight are fairly constant up to a depth of about 40 m, an assessment of fish numbers indicate a continual fall with depth (Figure 8). Beyond 50 m depth, 50% of the hauls recorded no fish compared to <1% of the hauls in the 10 m stratum.

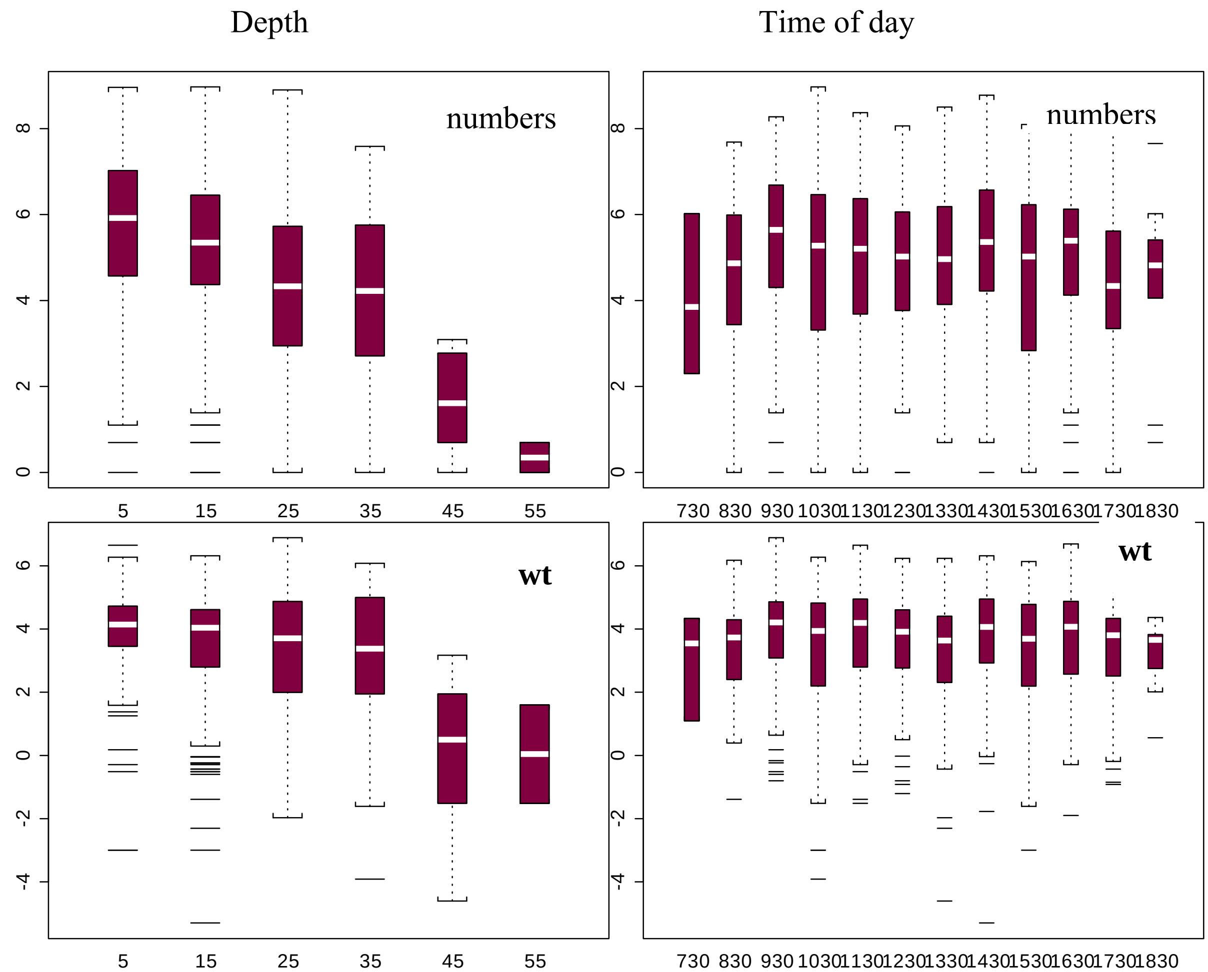


Figure 8: Boxplots of catch rates of Nile perch in trawl surveys with water depth and time of day, by log transformed numbers and weight (wt). Only stations were fish was recorded are plotted.

Median and mean catch rates from trawl surveys generally increased from the time of the inception of the project in 1997 up to a maximum in 2000/2001 and thereafter reduced (Figures 9 and 10). The differences are more pronounced in numbers than weight. There is a constant increase in catches from long dry seasons (December to February) to peak periods during the long rainy season (March – June) and from the short dry season (July-August) to the short rainy season (September – November) (Figure 11). Using numbers, fish caught during these rainy periods roughly coincide with high numbers of fish in the lake, indicating possible recruitment periods. Interactions between zone of sampling and other factors show that regardless of the zone (area) sampled, catch rates increased by year up to 2000/2001 and fell, they oscillated with months and strongly reduced with depth (Figure 10).

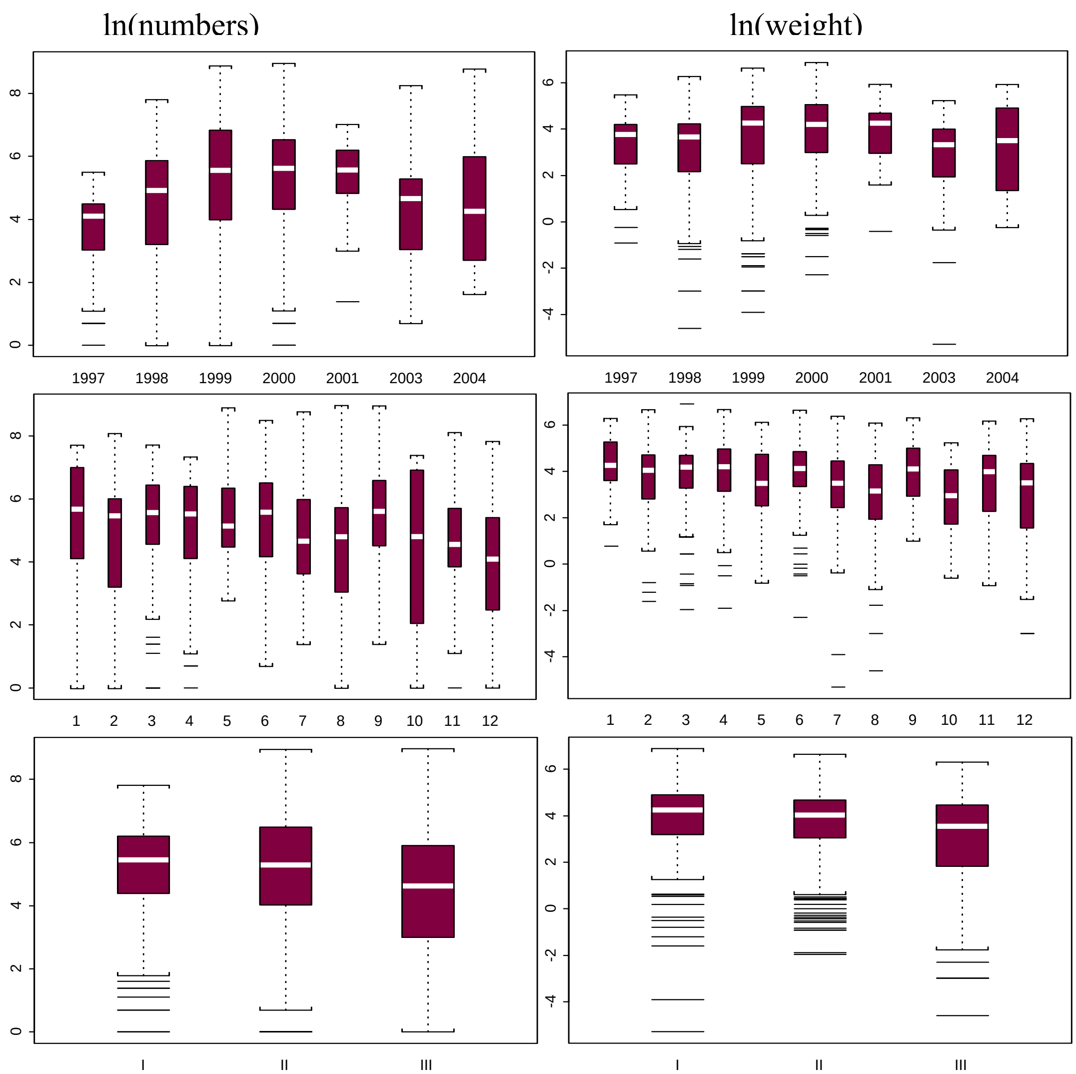


Figure 9: Box plots showing distribution of catch rates of Nile perch (by log transformed numbers and weight) from a bottom trawl in Lake Victoria Uganda by year (top), month (middle) and zone (bottom) (each haul took 30 minutes).

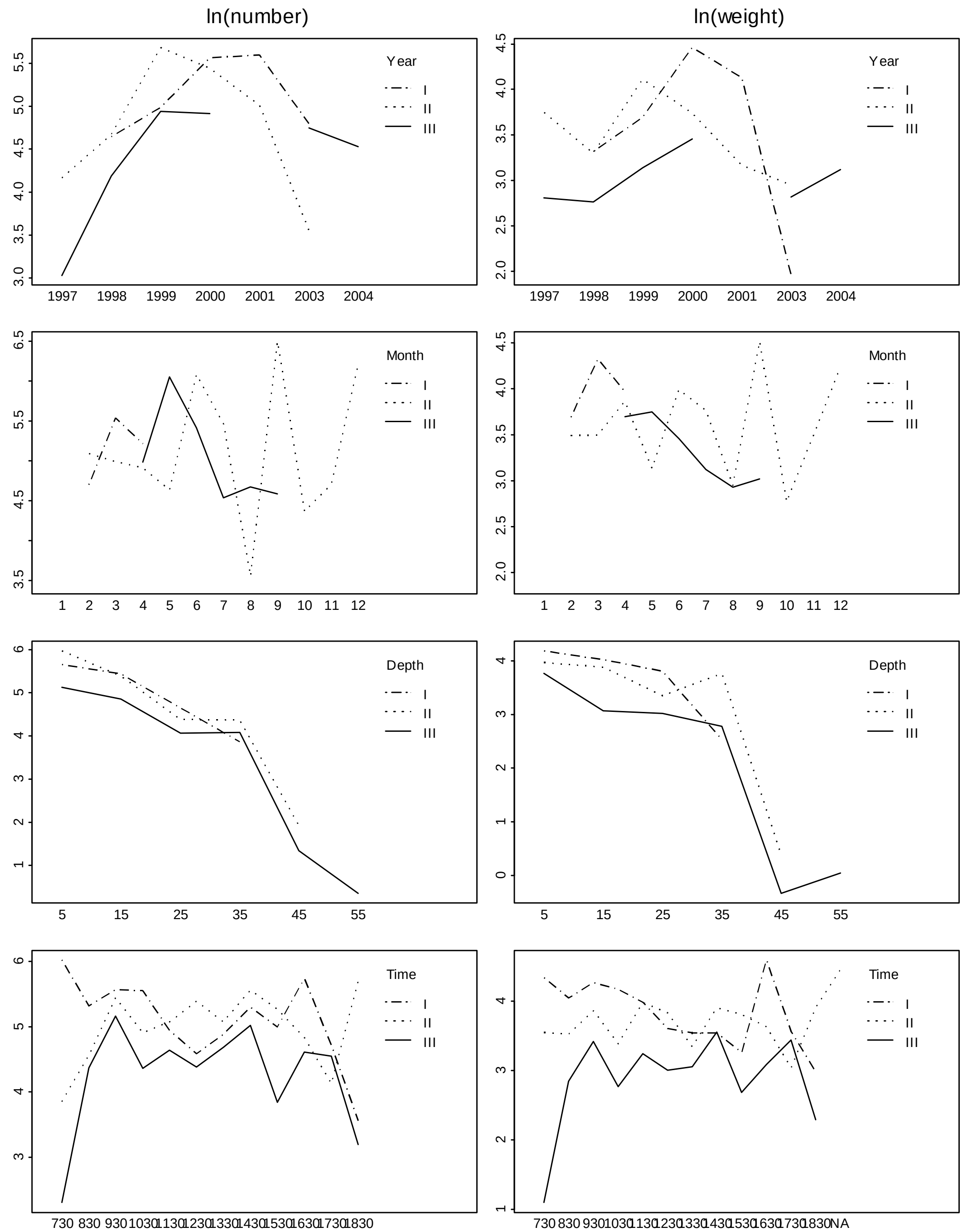


Figure 10: Comparison of trends in mean catch rates from trawl surveys in the three zones of the Ugandan portion of Lake Victoria across years, months, depth and time of day, by log transformed numbers and weight.

Analysis of variance (ANOVA) was used to test for significant factors affecting catch rates. The non-zero data were log transformed and tested using chi square to see if they were from the normal distribution. Results obtained ($\chi^2 = 6.4$, df = 3, p = 0.094) show that non-zero data are log normal. Log transformed data were therefore used to isolate the importance of factors affecting catch rates.

Five factors influencing catch rates were considered: year, month, time of day (hourly), zone and depth (10 m strata). A forward selection procedure was used to identify the significant factors. A full description is given in Appendix II and the results are shown in Table 1. Depth was the most important factor explaining 13.6% of the observed variance. Year, month and zone were the other significant factors although zone contributes little, explaining < 1% of the variance. Time of day was not a significant factor (p = 0.315, Table 1).

Table 1: Significance of factors affecting catch rates of trawl surveys from Lake Victoria Uganda.

Factor	**Df**	**Sum of Sq**	**Mean sq**	**F Value**	**Pr(F)**	**Sign.**
Depth	5	377.99	75.60	26.81	0.000	***
Year	6	198.04	33.01	11.70	0.000	***
Month	11	107.64	9.79	3.47	0.001	**
Zone	2	23.30	11.65	4.13	0.016	*
Time	11	35.85	3.26	1.16	0.315	NS
Residuals	719	2027.71	2.82			

4.1.8 Variation in mean length with depth

As a greater decline in catch by numbers than by weight with depth was observed (Figures 8 and 10), the relationship between fish length and depth was analysed. There was a positive correlation between the mean length of fish and average depth of the lake trawled (R = 0.458). Mean length of *Lates* increased with depth at least up to 40 m where sufficient observations were made (Figure 11). An increase in mean length of fish with depth, coupled with a reduction in numbers but constant weight with depth (Figure 8), indicates that shallow waters have high numbers but mainly small fish hence lower weight.This is an indication of large quantities of juvenile fish.

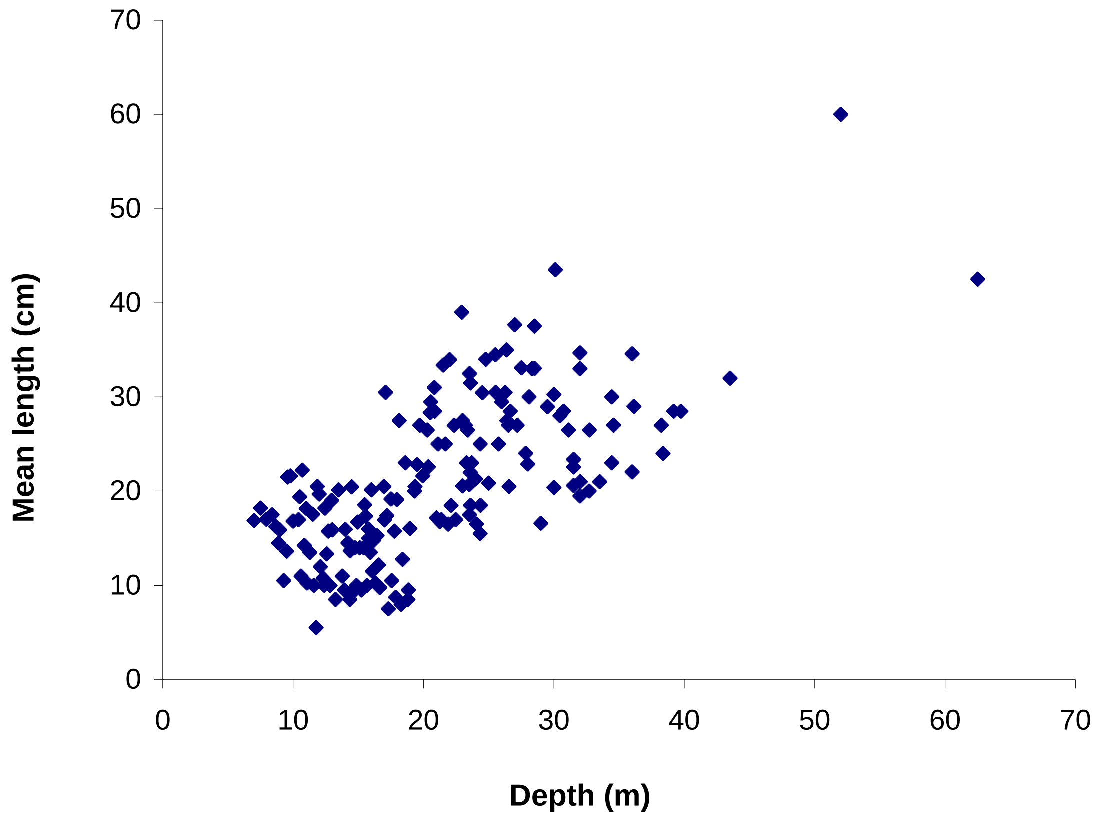


Figure 11: Mean length of Nile perch harvested at various depths using a bottom trawl net in Lake Victoria – Uganda.

4.2 Catch assessment surveys

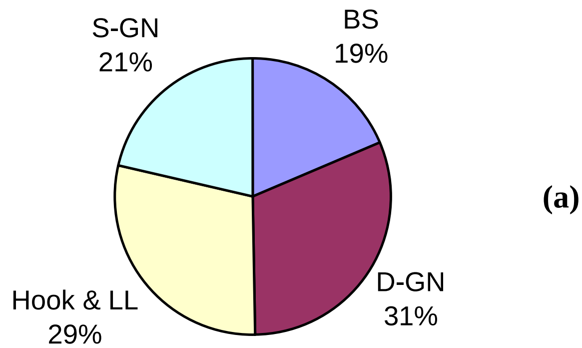
Onshore surveys of the fishing activities are carried out to determine the amount of fish being landed, the numbers and types of boats involved, the types and sizes of gears used, the mode of operation, the number of crew, the target fish species and where possible income derived from the fishing activity. The overall objective is to determine catch per unit effort of the various crafts and gears engaged in Lake Victoria fisheries. While at the landing site, fishing boats are randomly selected as they land in the morning/evening, their catch of the night/day assessed by taking total weight by species. Total length is taken for all the fish harvested by each gear used. Boats tend to specialise in one form of gear which may vary only in sizes used.

4.2.1 Catch per unit effort

Using data collected from landings at beaches from three lakeshore districts (Wakiso, Mukono, and Mayuge) and one Island district (Kalangala) of Uganda in 2003, proportional catches landed by each gear are calculated and presented in percentages (Figure 12). Double gillnets (D-GN), which are set and operated in deep offshore waters, land the largest (31%) proportion of Nile perch on the Ugandan portion of the lake

(Figure 12a), followed by hook and long lines (29%). Single gillnets (S-GN) contribute 21% of the catch. Despite being outlawed, beach seines (BS) are still landing a large amount of fish (19%). Gill nets (D-GN and S-GN) are by far still the most important gear used in the Nile perch fishery on the Ugandan section of the lake, contributing over 50% of the catches.

Catch rates (calculated as weight of fish (kg) /boat /gear / day or night) were evaluated from the four districts. Beach seines are prominent in three of the four districts having higher catch rates than other gears (Figure 12b). This could explain why they are still used despite being banned. According to frame survey data published by LVFO, there were still over 800 beach seines still operating on the Ugandan part of the lake by 2002. Beach seines are active gears and operated continuously which could explain the higher catch rates per boat per day as compared to the rest (passive mainly set and left to stay overnight). BS may not be very prominent in Wakiso due to its geographical location near authority with possible high levels of surveillance. D-GN are present in all districts but registered overall higher catch rates in the Wakiso district.



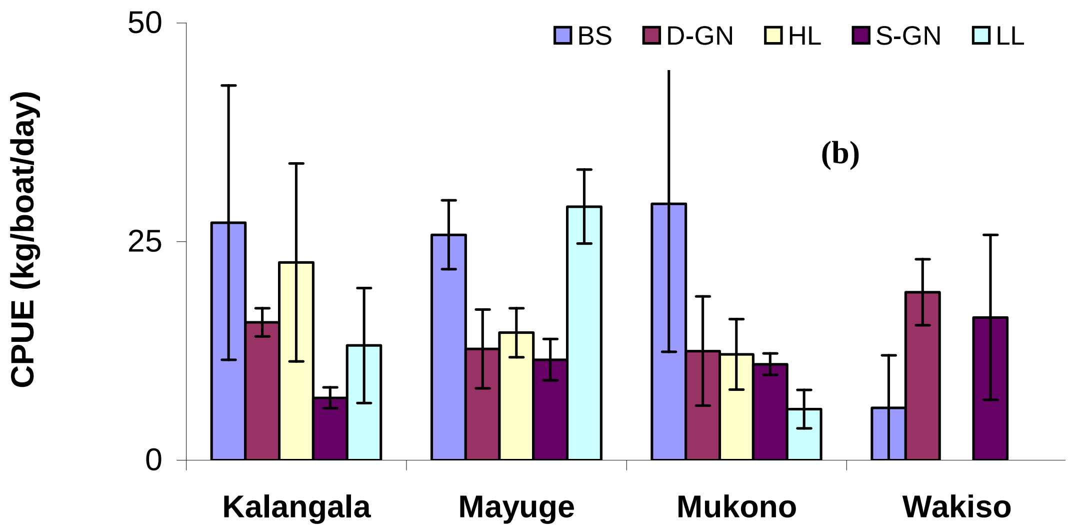


Figure 12: Contribution to total landings of various gears used in the Nile perch fishery (a) and mean catch rates of various gears from four lakeshore districts of Uganda (b) (± SE).

4.2.2 Length frequency distribution from CAS

Length frequency distribution of Nile perch harvested by the four main gears operating on Lake Victoria, Uganda is illustrated in Figure 13. Beach seines with a modal size less than 20 cm TL harvest large quantities of juvenile Nile perch (legal catch size 50 – 85 cm TL – slot size). Likewise, single gillnets that tend to be operated in shallow inshore waters (Muhoozi 2002) harvest much smaller fish (modal length 30 cm) compared to deep water operated double gillnets (50 cm). Length frequency distributions here were fitted to the logistic length selection curve in FISAT and used to determine the selection patterns that yielded the selection parameters for each gear used in yield per recruit analysis.

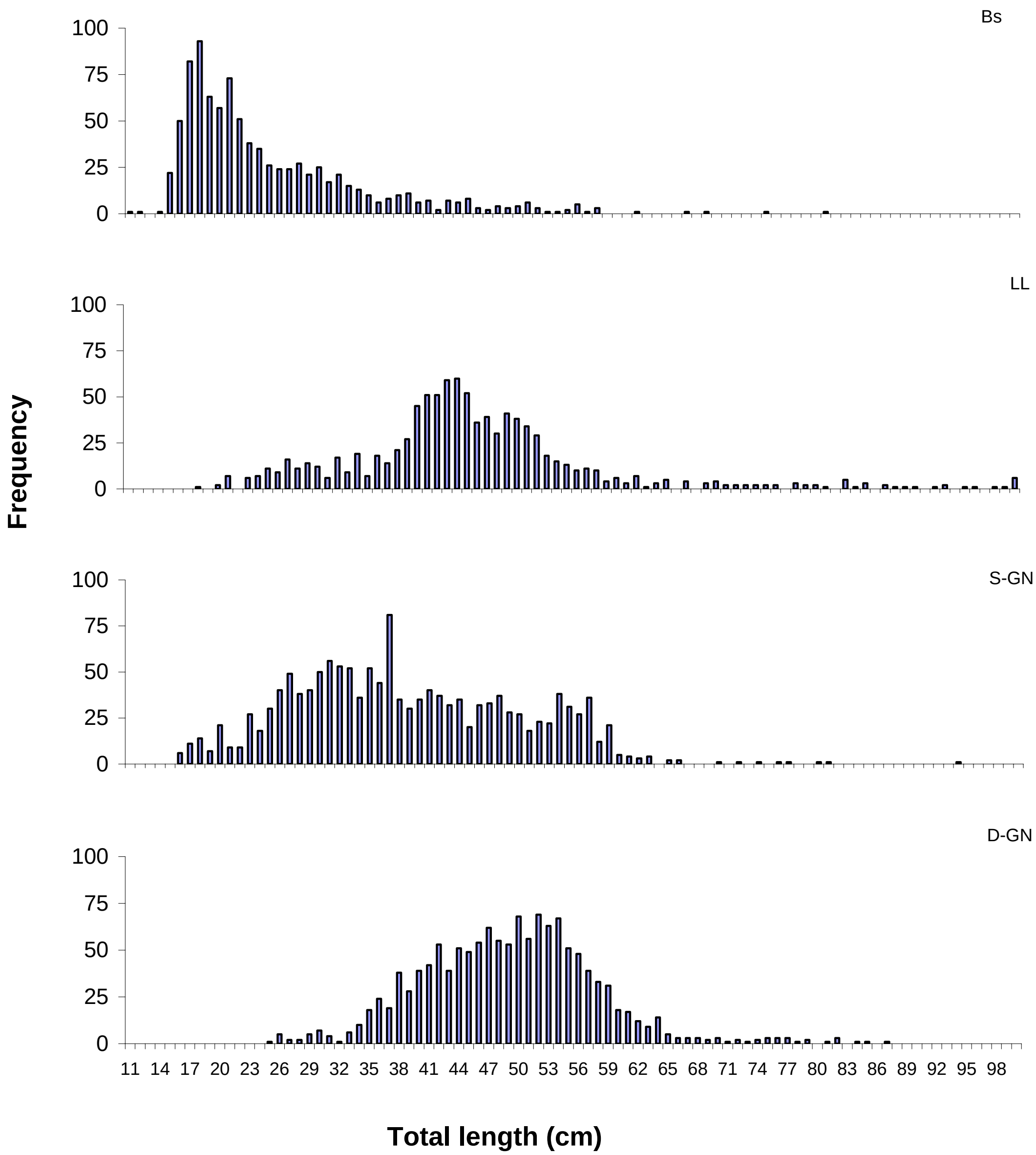


Figure 13: Length frequency distribution of Nile perch harvested by the four main gears on Lake Victoria, Uganda.

4.2.3 Gear selection patterns

Using FISAT, the probability of capture of fish using the three main gears on the Ugandan portion of the lake was estimated. The length at first capture ($L_c = L_{50}$), which is the length at which 50% of the fish that encounter the gear are likely to be retained, was lowest for the beach seine (15.5 cm), followed by hook and line fishery (20.41) and largest in the gill net fishery (31.79 cm, Table 2). For the purpose of this study L_{50} of each gear was used in the estimates of yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R). A knife-edge selection (Beverton and Holt 1957) Not on reference list was assumed indicating that beyond a certain size all the fish encountered are retained by the gear. This is not necessarily the case because selectivity is primarily determined by availability of the fish to gear and gear selection pattern. In the case of the beach seine (operated in inshore areas), the large fish that tend to be offshore may not be available to the gear. Gill net and hook selection curves are characterized by strong left-hand *and* right-hand selection. With a knife-edge selection, whereas numbers below L_{50} are underestimated, those above are overestimated. By numbers they cancel out but those above L_{50} weigh more since weight is proportional to the cube of length. However, the knife-edge selection was used on the assumption that the numbers decline above L_{50} due to unavailability of large fish to the gear. All the gears used in the fishery are of varying sizes targeting virtually all sizes of fish. Therefore, reduction in the proportion of fish above L_{50} is largely due to unavailability rather than selection.

Using length-converted catch curve analysis in FISAT, with the length frequency distribution with constant class size (1 cm) from the three gears employed in the fishery as input data, L_{∞} = 221 (Muhoozi 2002) and K = 0.18 (Muhoozi 2002, trawl survey), total mortality Z was estimated as 2.2. In using this method, it was assumed that catch length frequency data was taken from a steady-state sample where recruitment is assumed constant. Using the mean annual temperature 27^{o} C, natural mortality M was estimated from Pauly's empirical formula as 0.33. With Z and M estimated, the fishing mortality F was calculated as 1.87 and exploitation rate (E = 0.85) determined. The length-converted catch used in this study came from a combination of gears (beach seines, hook and line fisheries, and gill nets). All the gears used were of varying sizes, for example gill nets varied from 3” (76 mm stretched mesh) to 10” (254 mm). It is therefore assumed that all these varying gears coupled with varying sizes, target virtually all sizes of fish and therefore, unavailability of large fish is purely due to unavailability to gear not selection.

From the length-converted catch curve extrapolation of a regression line drawn was used to approximate the probability of capture for each length group (Figure 14), which was then used to estimate the selection parameters based on the extrapolated points (Gayanilo *et al*. 1997). The probability of capture was plotted using the running average technique to estimate selection parameters for each gear (Table 2 and Figures 15 a, b, & c).

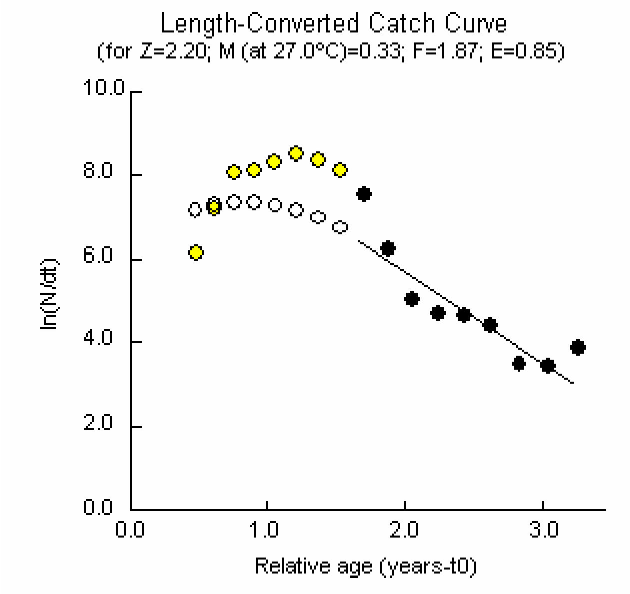
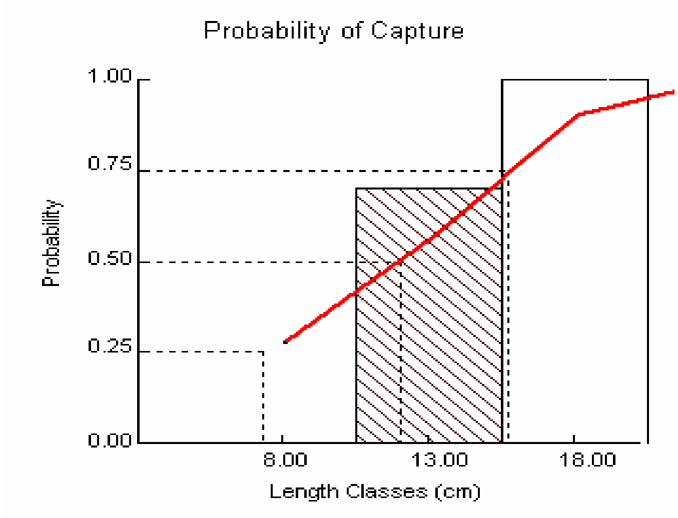


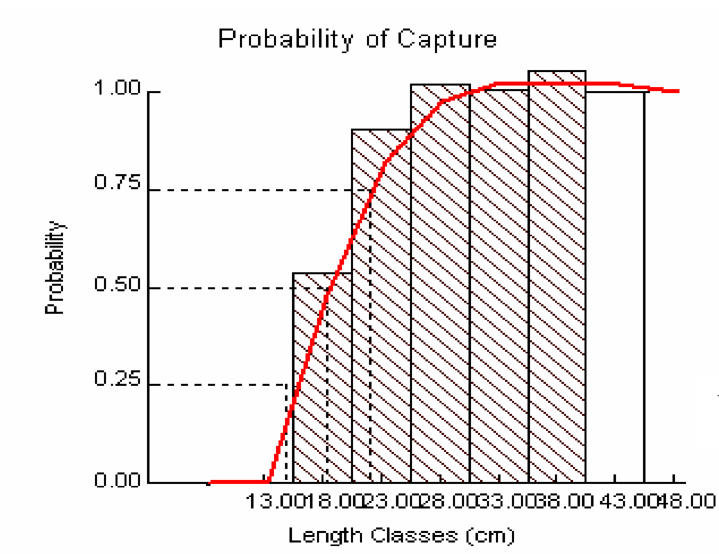
Figure 14: Length-converted catch curve used to estimate Z from FISAT.

Table 2 : Estimated sizes at 25, 50, and 75% probability of capture of three artisan fishing gears used on Lake Victoria, Uganda.

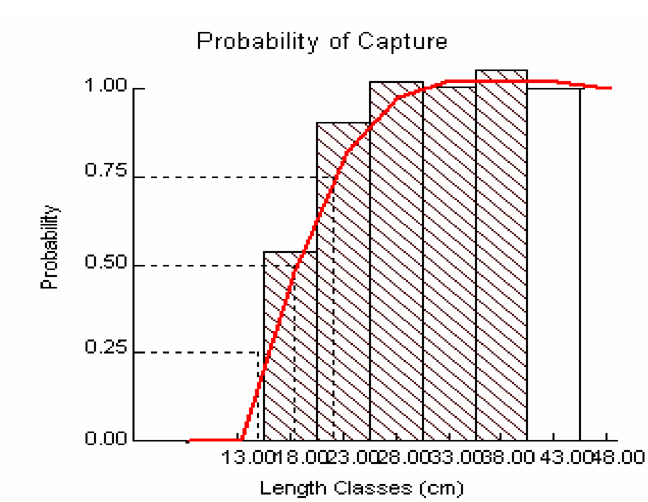
Gear	L_{25}	L_{50}	L_{75}
Beach seine	11.75	15.50	19.25
Hook and line fishery	15.46	20.41	27.22
Gill nets	24.29	31.79	43.07



a) Beach seine



b) Hook and longline fishery



c) Gillnet selection patern

Figure 15: Selection patterns of the three gear types used in the Nile perch fishery on Lake Victoria, Uganda.

4.3 Yield per recruit and spawning stock biomass

Growth and mortality parameters determined in the previous sections were used in the yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) estimates. Growth parameters were determined from the trawl survey data while mortality and selection parameters were determined from the catch assessment survey data. Established parameters were input into the yield per recruit length-based simulation model in an Excel spreadsheet (Appendix III), and then the desired parameters were varied to determine their effect.

4.3.1 Yield per recruit based on current fishing pattern

Estimated yield per recruit of the Nile perch fishery on the Ugandan part of the lake based on the current fishing pattern is given in Figure 16. Fishing mortality that gives a maximum yield (F_{max}) is estimated to be 0.21, while the actual fishing mortality calculated above is 1.87. The current fishing mortality yields 535.6 g per recruit. The current YPR could be raised by a factor of 5 to approximately 2800 g if fishing mortality was maintained at $F_{max.}$ Using a precautionary approach by maintaining fishing mortality at 0.1 (F0.1) could rise in a four fold increase in YPR to about 2400.

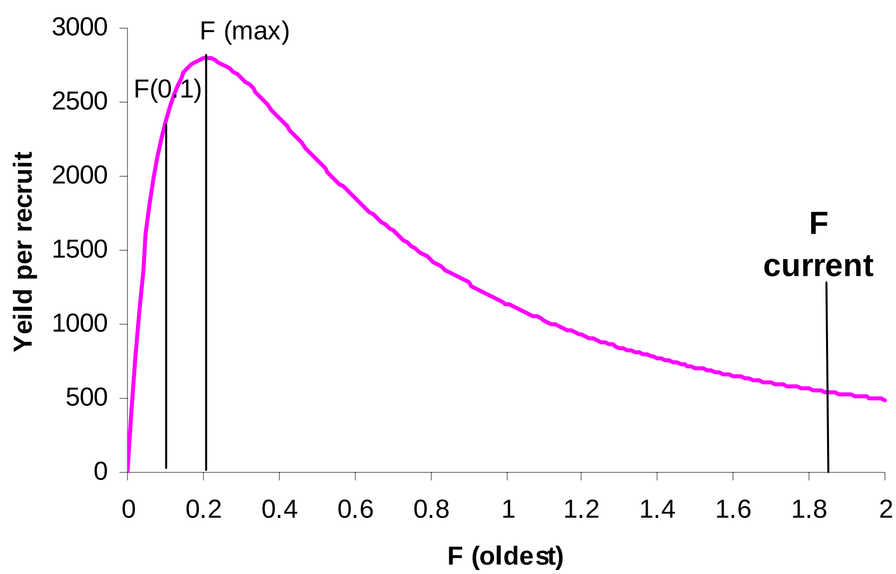


Figure 16: Current yeild per recruit curve at various levels of fishing mortality.

4.3.2 Effect of gear selection patterns on YPR and SSB/R

Keeping all other parameters constant and varying the selection pattern according to those determined for the different gears (Table 2), a YPR graph generated indicates maximum YPR when using GN (3105) followed by hooks (2852) and least in BS (2794) (Figure 16).Whereas maximum YPR is attained at an effort of 0.21 for BS and hooks, using GN maximum, YPR is obtained at a higher effort (0.24). All gears show a high rate of reduction in YPR with an increase in effort. The highest rate in reduction of YPR with effort was observed in the beach seine (0.91) and lowest when using GN (0.58) (Figure 17). Using gillnets in exploitation, the fishery can tolerate wide changes in effort compared to the use of BS. Hooks are intermediate.

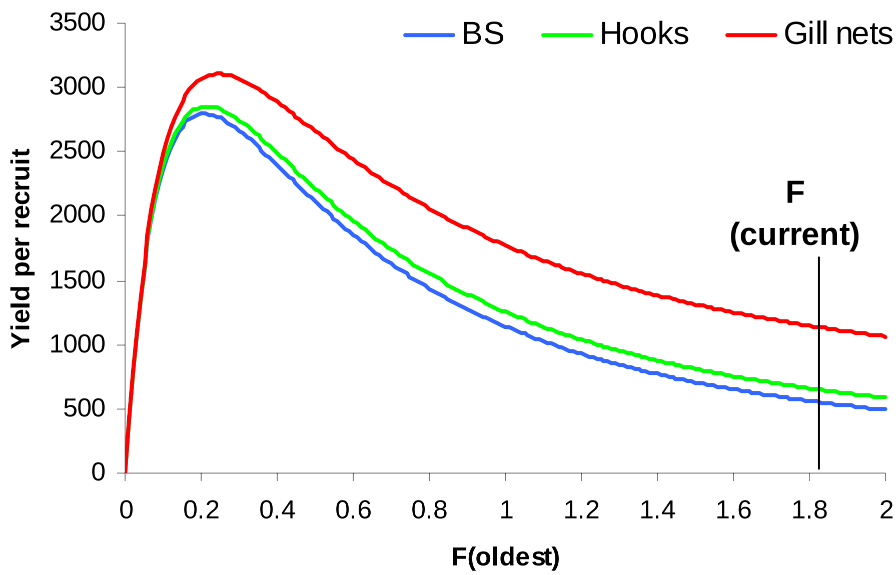


Figure 17: Yeild per recruit at various levels of fishing mortality using three differenet gears in the Nile perch Fishery.

Unlike YPR estimates, which show clear differences amongst gears used, SSB/R for Nile perch in Lake Victoria Uganda did not vary much with gears (Figure 18). Although SSB/R for each value of effort using different gears shows a similar trend as YPR with more effect being from beach seines, then hooks and finally gill nets, the difference is much less pronounced. This could be associated with the fact that all these gears harvest fish below the size at sexual maturity. In other words, all gears harvest fish below 60 cm TL yet size at maturity was estimated to be 56 and 70 for males and females respectively and 59 cm TL average (Section 4.1.6). The gears are therefore harvesting mainly juveniles and hence no difference is observed in the SSB/R relationship.

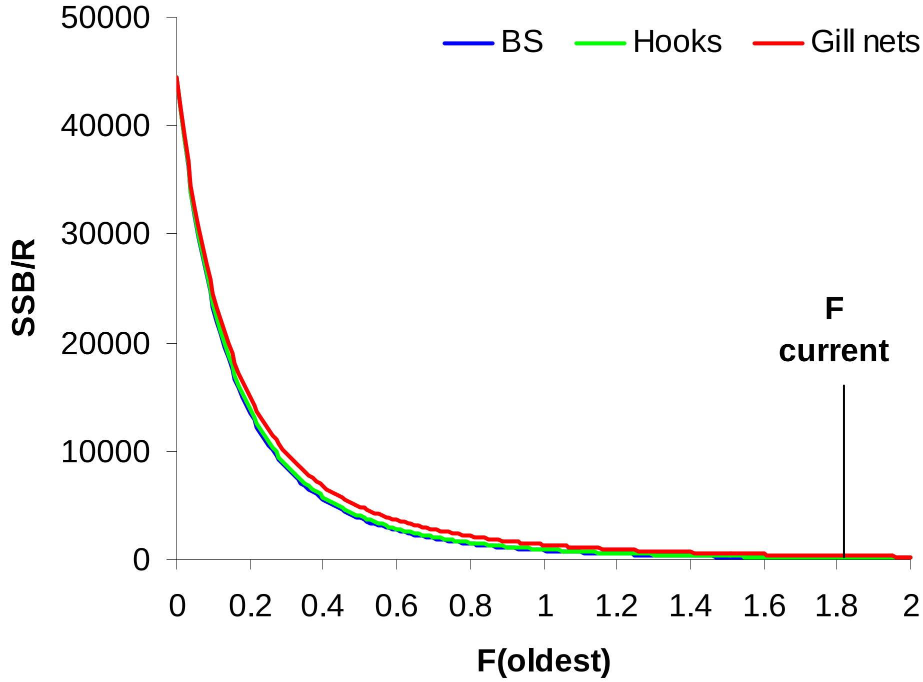
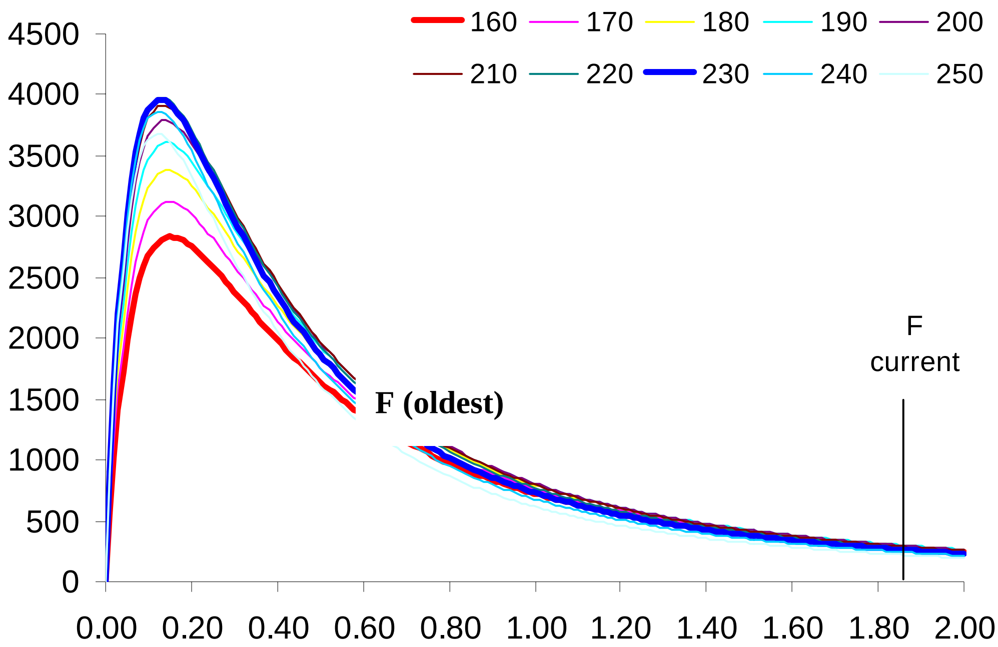


Figure 18: Spawning stock biomass per recruit at various levels of effort using three different gears in the Nile perch fishery.

4.3.3 Effect of estimated growth rate on YPR and SSB/R

Several studies on growth and mortality of Nile perch on Lake Victoria have estimated varying growth parameters since its introduction into the lake. In this section the effect of various combinations of length at infinity and growth constant K were investigated. The YPR at F_{max} varies in the range of 2800 – 4000 g depending on the growth assumptions (L_{∞} and K) used. A sharp reduction in YPR with increased fishing mortality is observed for all cases. By decreasing fishing mortalities from the estimated current F (1.87) to F_{max} = 0.22, the YPR will increase by a factor of 5 - 8.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5 DISCUSSION

A striking difference is observed in the size structure of fish harvested in the monthly trawl surveys and the catches from the fishermen. Whereas in the surveys the modal classes of fish measured were below 30 cm TL, in the commercial fishers' catches, the modal classes were above 30 cm TL (with the exception of the beach seine). A possible cause could be unavailability of the large fish to the bottom trawl used. Commercial fishers use pelagic set gill nets and long lines and harvest larger fishes compared to the bottom trawl used. Trawl survey data was therefore only found useful in providing recruitment indices as opposed the overall population structure. Proper assessment of the population dynamics will therefore require a combination of trawl and catch assessment data. Aspects of pelagic trawling, hydro acoustic surveys and pelagic gill netting could give a better picture of what the pelagic zone of the lake holds. Adult Nile perch may not be purely dermersal or may be more pelagic in search of prey, at least at some times of day.

Low catches of fish in deeper (over 55 m deep) waters (Figures 8 and 10) could be related to an anoxic condition within those areas. It was reported (Ogutu-Ohwayo *et al*. 2002) that anoxia in Lake Victoria has reduced the volume of water occupied by fish by approximately 50%. Anoxic conditions are more pronounced during the period of thermal stratification (September to April), which has become more evident in recent years. During the mixing period (June-July), minimum water temperatures were 0.5 ^{o}C higher in 1990 than in the 1960s (Ogutu-Ohwayo *et al*. 2002). During thermal stratification, decomposing organic matter that includes high algal biomass depletes oxygen leading to anoxia in deep waters. Nile perch that is known to require sufficient oxygen cannot tolerate such areas.

The monthly survey design carried out in different zones each month could not give a proper comparison of indices of recruitment among the three zones. Some months were missed out and therefore comparisons are more difficult. Despite the fact that the stations had theoretically been fixed in terms of boxes, practically the sampling remained random in the boxes. Equal numbers of hauls were not taken per box raising sampling variability. Sampling was also done during day time only. Aspects of diurnal variations in spatial and temporal distributions of fish were therefore not properly examined.

Under the current design in the monitoring program during IFMP where the three zones will be sampled quarterly within the same period may yield better indices. Under this program the stations have been fixed and according to the standard operating procedures, variability in the sampling regimes is to be minimized as much as possible.

The use of double gillnets that are operated in deep water and harvest relatively large fish would most likely result in a higher YPR than all other gears including single gillnets that are set and operated in shallow waters with fish of small average size.

Growth parameters of Nile perch in Lake Victoria have been estimated by various authors giving different sets of L_∞ and growth constant K. This study has established that K is related to L_∞, the higher the rate of growth the lower the L_∞ reached by the fish. However, despite the large size of L_∞ reported for Nile perch in Lake Victoria, the biggest fish recorded in the three year trawl survey in the Ugandan section of the Lake was 144 cm TL. While this size is larger than 93 cm, which was reported (Hopson 1972) in Lake Chad (native habitat), it is much lower than all estimates of L_∞ in Lake Victoria where it was introduced close to a half a century ago. The implication is that with changes in its new habitat Nile perch may no longer grow to the sizes which were estimated years after its introduction. Lack of use of hard parts to determine fish age still remains a big hindrance to a proper estimation of L_∞ based on current samples. Most of the figures quoted have mainly been length based.

The length-weight relationship of a fish is an important factor in its productivity. Just like other growth parameters L and K, length-weight parameters “a” and “b” of Nile perch which determine the condition, have also been changing. After its introduction, the condition factor has changed from about 1.4 in the 1960s to 1.2 in the late 1990s when the haplochromines (its main prey at introduction) had crumbled, to the present 1.31 determined in this study. This value is close to Lake Albert (its natural habitat) estimated at 1.3 (Ogutu-Ohwayo *et al*. 2002). With the current reported resurgence of haplochromies in the lake (Schindler *et al.* 1998, UNECIA 2002, Balirwa *et al.* 2003), it appears that the Nile perch condition in Lake Victoria may stabilize at about the same value as in its natural habit. Likewise, size at sexual maturity has continued changing (section 2.1). The current study estimated Nile perch to reach sexual maturity at 56 and 70 cm TL for males and females respectively. However, the number of samples in the critical length group 50 – 80 cm TL in the trawl samples were very low, therefore the given values are not precisely estimated.

This study has demonstrated that Nile perch distribution in the lake may not be as anticipated. It exhibits spatial distribution with juveniles occupying the shallow inshore waters and possibly temporal distribution with the deeper zones remaining largely anoxic and therefore limiting adults in the pelagic zone. It was shown that the mean size of fish tends to increase with distance into the open lake, which agrees with observations by Ogari (1984) of the tendency of fish size to increase with depth. It therefore follows that gears that are restricted to shallow areas like beach seines and single gillnets (Muhoozi 2002) generally harvest small and juvenile fish that aggregate in shallow inshore areas. The result is strongly left skewed length frequency distributions from such gears with low L_{50} demonstrated by the beach seine in this study.

Gears used by commercial fishers on the Ugandan part Lake Victoria show varying selection patterns. Gears such as the beach seine show a strong left skewed distribution, others such as gill nets show typical gill net type selection with clearly defined ascending and descending loops. In the simulation for YPR and SSB/R a knife-edge type of gear selectivity was assumed. All fish below a certain size invariably escape from the gear while all those above that size are retained by the gear. It is assumed further that the observed drop in numbers of fish in the length distribution samples by gear is largely due to unavailability of the large fish to the gear. It is therefore assumed that the shape of the selection curve is reflecting the actual size structure in the population with respect to larger fish. It is, however, known that when the fish size becomes so large that they cannot intrude far enough into the gear to become entangled by the opercular bones (gill covers) or teeth, maxillaries, or when the fish have attained sufficient weight or strength to break through a mesh to freedom (or to straighten a hook or break a line) they may not be retained by the gear. This is, however, countered by the fact that for the gears used, sizes varied and therefore targeting a variety of fish sizes, thus taking almost all sizes. The knife edge selection used under this assumption is appropriate.

This study has demonstrated that the gear used has profound effect on the resultant yield per recruit in the Nile perch fishery. Gears with low length at 50% probability of capture harvest small juvenile fish before reaching optimum size and hence a lower maximum YPR is produced. This agrees with the observation that high exploitation of fish below 60 cm in Lake Victoria by gill nets, long line, and beach seines leaves little opportunity for fish to escape and grow to maturity. Whereas, data analysed in this study and information generated from literature indicate that Nile perch in Lake Victoria mature well above 50 cm, close to 80% of the catches from fishermen lie below 50 cm TL. Even then, the law on slot size proposed minimum size of harvestable fish of 50 cm TL, yet size at first maturity is higher. The upper limit of the slot size (85 cm) was proposed to protect the mature/pawning females that are few in the population but tend to dominate above this size. It is not very clear why the lower limit was put at 50 cm TL when size at 50% maturity is higher. Traditional fisheries advice has always based on size at sexual maturity to fix minimum harvestable size.

6 CONCLUSIONS AND RECOMMENDATIONS

Results from the survey indicate that larger fish are not well represented in the trawl samples. They are either unavailable to the gear or in low numbers in the population. But since catch assessment surveys indicate the sizes harvested by artisanal fishers are larger than those from the trawl surveys, unavailability of larger fish to the trawl gear could account for the low proportion of larger fish in the samples. It is therefore recommended that trawl surveys should be supplemented by pelagic operated gears such as double drifting gill nets (used by artisanal fishers) and pelagic trawling.

It was discovered that during the monthly trawl sampling, zones were sampled in different months and hence results could not be compared well. In order to compare indices from different stations, seasonality is an important factor and therefore different areas have to be sampled within the same period. It is therefore recommended that during the IFMP monitoring phase, all the zones should as much as possible be sampled within the same period.

Stations were found to be fixed but the sampling within the stations were more random and therefore a high degree of variability was observed in sampling. It is therefore recommended that stations should be fixed and sampling regimes balanced as much as possible to reduce bias. All stations should be given equal sampling opportunity.

Variability in catch rates were observed for early morning and late evening hours of the day as compared to the rest of the day. Whereas this could largely be attributed to the few stations sampled during these periods, the timing could also be a factor. Given constant diurnal variations in oxygen concentrations and temperature fluctuations, night trawls could easily isolate the role of time of day to fish catch rates. It is therefore recommended that day and night trawls be undertaken.

It was discovered that the depth of the lake is the most important factor in determining catch rates of the trawl surveys. Catch rates decreased with depth until it disappeared beyond 55 m deep. Zoning of the lake for the purpose of trawl surveys could be based on depth rather than zone where catch rates were not significantly different. It is therefore recommended that future demarcation of trawl operational zones be based on depth rather than physical features.

Simulations in this study have proved that the selection pattern of different gears have profound effects on YPR. Gears with lower sizes of probability of capture yield lower YPR. Beach seines were found to harvest more juveniles and yield least YPR and SSB/R. Though these gears are outlawed, they are still in operation in the fishery. It is therefore recommended that surveillance and co-management that will lead to reduction in these illegal gears be streamlined and supported.

Various studies of growth and mortality of Nile perch in Lake Victoria have yielded different combinations of length at infinity and growth constant K. It was however, discovered in this study that regardless of L_∞ used, fishing effort employed has more effect on YPR and SSB/R. Given the high current fishing mortality (F=1.87) estimated in this study, a substantial gain in yield per recruit and overall yield seems obvious by reducing the overall effort. This conclusion is not sensitive to assumptions about fishing pattern, growth rate and a given range of natural mortality.

With the introduction of Nile perch into Lake Victoria , the ecology of the lake has changed and there are indications that the ecosystem in the lake, together with fishery, are still undergoing phases of evolution and therefore more studies need to be undertaken to constantly monitor the dynamics of this important resource and resource base.

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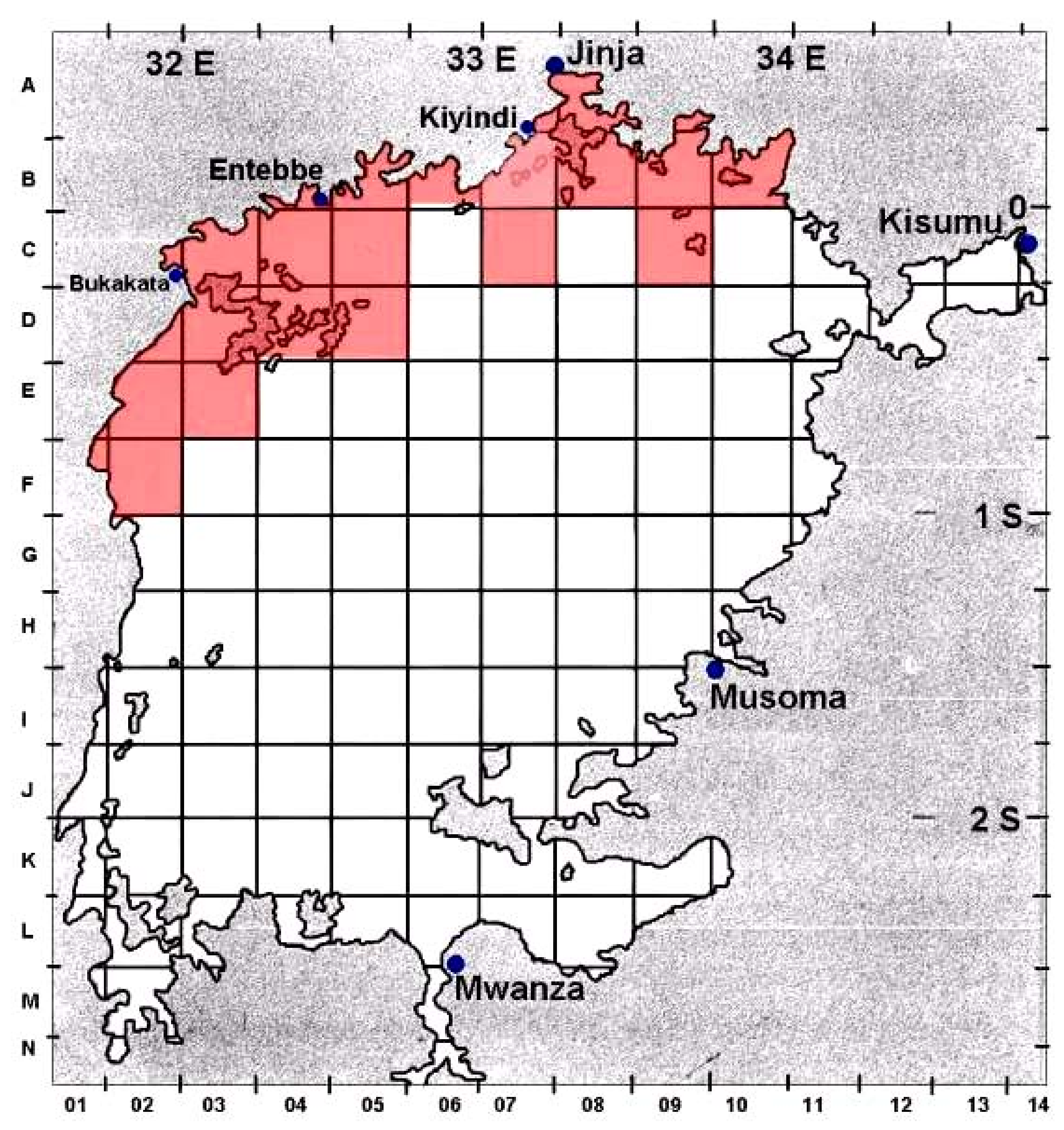
APPENDIXES

Appendix I: Map of Lake Victoria showing new grids used in the monitoring phase of program (each grid 15 X 15 nuatical miles



M
ln

|

scale: 2.820186

Df Sum of Sq RSS Cp
<none> 2770.524 2776.165
factor(year) 6 214.2006 2556.324 2595.806
factor(month) 11 206.1590 2564.365 2632.050
factor(zone) 2 61.8219 2708.703 2725.624
factor(depth2) 5 377.9929 2392.532 2426.374 (Identified as the most significant factor)
factor(time2) 11 56.0135 2714.511 2782.195

lnum ~ factor(depth2)

scale: 2.820186

Df Sum of Sq RSS Cp
<none> 2392.532 2426.374
factor(year) 6 198.0357 2194.496 2262.180 (Identified as the 2nd most significant factor)
factor(month) 11 205.8195 2186.712 2282.598
factor(zone) 2 47.4418 2345.090 2390.213
factor(time2) 11 59.6525 2332.879 2428.765

lnum ~ factor(depth2) + factor(year)

scale: 2.820186

Df Sum of Sq RSS Cp
<none> 2194.496 2262.180
factor(month) 11 **107.6354 2086.861 2216.589(Identified as the 3rd most significant factor)**
factor(zone) 2 40.0890 2154.407 2233.372
factor(time2) 11 38.4544 2156.042 2285.770

lnum ~ factor(depth2) + factor(year) + factor(month)

scale: 2.820186

Df Sum of Sq RSS Cp
<none> 2086.861 2216.589

factor(zone) 2 23.30179 2063.559 2204.568 (Next)
factor(time2) 11 37.44497 2049.416 2241.188

lnum ~ factor(depth2) + factor(year) + factor(month) + factor(zone)

scale: 2.820186

	Df	Sum of Sq	RSS	Cp
<none>			2063.559	2204.568
factor(time2)	11	35.84467	2027.714	2230.767

Finally Overall analysis of variance results in

Response: lnum

Terms added sequentially (first to last)

	Df	**Sum of Sq**	**Mean Sq**	**F Value**	**Pr(F)**
factor(**depth2**)	5	377.993	75.59858	26.80623	0.0000000
factor(**year**)	6	198.036	33.00594	11.70346	0.0000000
factor(**month**)	11	107.635	9.78504	3.46964	0.0000980
factor(**zone**)	2	23.302	11.65089	4.13125	0.0164457
factor(**time**2)	11	35.845	3.25861	1.15546	0.3149169
Residuals	719	2027.714	2.82019		

Appendix II. Analysis of Variance in catch rates of trawl surveys through -Single term additions

PARAMETERS	
Length at start	10
Von Bertalanffy Growth Equation	
Linf	221
K	0.18
Length - Weight equation	
Ln(Alpha)	-4.0342
Beta	2.9082
Fishery Selectivity	
Knife edge (0 or 1)	1
Alpha	-8.574
Beta	0.226
Fully recruited length	10
Natural Mortality	
M of oldest fish	0.2
Constant value (0 or 1)	1
Alpha	-8.574
Beta	0.4
Maturity	
Alpha	-8.574
Beta	0.306

$$L_{t+\Delta t} = L_t + [L_\infty - L_t][1 - e^{-K\Delta t}]$$

$$W = \alpha L^{\beta}$$

$$Y_L = 1/\left(1 + e^{-(\alpha + \beta L)}\right)$$

$$N_{t+\Delta t} = N_t e^{-\Delta t(M_t + F_t)}$$

$$\Delta C_t = F_t/(F_t + M_t)\left(1 - e^{-\Delta t(F_t + M_t)}\right)N_t$$

Note that the logistic function (YL above) was used in this report to model Maturity
But can also be applied to gear selectivity and natural mortality
Take not that these factors are modeled as a function of length not age

Appendix III : Model used in YPR and SSB/R analysis