Lake Victoria Environmental
Management Project

Knowledge and experiences gained from managing Lake Victoria ecosystem

A publication of the Lake Victoria Environmental Management Project (LVEMP)

The World Bank GEF

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PREFACE

The Lake Victoria Environmental Management Project (LVEMP) is a comprehensive regional effort by the Governments of Tanzania, Kenya and Uganda to reverse the environmental and natural resources degradation of Lake Victoria Basin. The five-year project (July 1997 -June 2002) was initiated under a Tripartite Agreement signed on 5th August 1994 between the three riparian countries to achieve the following main objectives:

(i) Maximize the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease-free environment;

(ii) Conserve biodiversity and genetic resources for the benefit *of* the riparian communities and the global community; and

(iii) Harmonize national management programs in order to achieve, to the maximum extent possible, the reversal for increasing environmental degradation.

Prior to the implementation of LVEMP, there was a scarcity of reliable scientific information on the state of the ecosystem of Lake Victoria, which has been undergoing rapid deterioration from the pressures of rapid population growth and increasing socio-economic activities in the basin.

The Project has so far accumulated a substantial amount of information, knowledge and experiences, which could be shared with stakeholders. A Regional LVEMP Scientific Conference of its kind was held in Kisumu, Kenya from 3rd - 7th December 2001. The conference brought together over 200 delegates from East African Community (EAC) Partner States, all with a common purpose of exchanging ideas on the status of the resources of Lake Victoria Basin. A total of 55 papers were presented in various disciplines covering Land use, Water Hyacinth, Fisheries Research and Management and Water Quality. The overall picture given by the spectrum of papers is critical in defining the trend in ecosystem changes and assessing the impact of present and future restoration measures.

This book which is a compilation of selected scientific papers, aims to disseminate information that are focusing on addressing the problems facing Lake Victoria and in particular the outcomes of recent resources management interventions in the catchment.

The book is intended for use by water resources managers, environmental regulation agencies, fisheries resources managers, wetland managers, agricultural and forestry extension staff, social scientists, university teaching staff, researchers and environmental funding agencies operating in Lake Victoria basin.

Christopher M. Nyirabu
Regional/National Executive Secretary
September 2002
Dar es salaam, Tanzania

ACKNOWLEDGEMENT

A Regional Scientific Conference on Lake Victoria Basin was held in Kisumu, Kenya on 3rd – 7th December 2001. The conference was organized by the Lake Victoria Environmental Management Project (LVEMP) with support from the Governments of the East African Community (EAC) Partner States: Kenya, Tanzania and Uganda; International Development Agency (IDA) and Global Environment Facility, through the World Bank.

LVEMP is greatly indebted to all institutions and persons, who in one way or another participated in making the scientific conference a success. The project would like to appreciate the effort of all authors and presenters of the scientific papers; those who reviewed the manuscripts and those who attended the conference. You made the conference.

Special gratitude goes to the Regional Scientific Conference Organizing Committee for the exemplary work it performed right from the inception of the conference to the publication of the conference papers. To be able to achieve the conference objectives, this committee was assisted by other co-opted and substantive committees. Notable among these were: the National Organizing Committees in the three EAC Partner States; the Programs and Book of Abstracts Preparation Committee; the Procurement Committee for ensuring timely purchases and provision of supplies for the preparation of the conference; and the Logistic Committee. The Project highly appreciates the personal and collective roles played by all members of these sub-committees towards the successful conclusion of the conference.

The rapporteurs who were drawn from the Partner States performed a commendable task. Having sat tirelessly through and beyond the sessions to compile the daily deliberations of the conference, this team is highly commended for its exemplary performance and for "a task well done".

Last, but not least, the Project wishes to acknowledge all session chairpersons, the hospitality teams (security and host institutions), and the conference director for the impressive manner in which they handled their respective roles throughout the duration of the conference. Sessions were lively, timely, safe, and adequately informed.

Thank you all and congratulations for a successful Regional Scientific Conference whose theme was "*sharing knowledge and experience of Lake Victoria Environmental Management Project for enhancement of Environmental Conservation in Lake Victoria*".

Lake Victoria Environmental Management Project
August 2004

INTRODUCTION

Lake Victoria is considered one of the most important shared natural resource of Eastern Africa. The Lake Basin supports about 30 million people one million of whom are employed formally or informally in fish related activities. The fishery of Lake Victoria is a major source of income to the fishing communities, Government tax revenue and protein for the local communities. Lake wide fish production is estimated at about 600 metric tones annually with Tanzania landing 40%, Kenya 35% and Uganda 25%. In recent years the Lake has become an important source of export earnings for the riparian countries through the Nile Perch Fishery – the largest inland fishery in the World.

The Lake Basin is a rich agricultural area and is of global significance in view of the biodiversity of its flora and fauna particularly the fishes endemic to Lake Victoria and has a great potential for tourism. The Lake is a source of water for agricultural, household and industrial use, wastewater disposal and hydroelectric power. Lake Victoria is the source of River Nile, an important asset for all countries within the Nile Basin. The waters originating from the Lake provide hydropower through its only outlet at Owen Falls in Uganda and other power plants lower down the river in Sudan and Egypt. Based on the socio-economic importance of the Lake Basin, the three East African Community (EAC) Partner States have declared the Lake Victoria Basin an Economic Growth Zone.

The resources of Lake Victoria Basin have not been harnessed and utilized in a sustainable way resulting in the current scenario where there is decline in biodiversity and apparent disappearance of vital species; deterioration of water quality caused by human waste, urban runoff, effluent discharges from industries; invasion of water hyacinth with significant social economical and environmental impacts to the Lake Basin; unsustainable utilization of wetlands which has negatively affected the buffering capacity of the wetlands; poor land use systems resulting in deforestation, serious soil erosion and farmland degradation with negative consequences in land productivity.

Through Government Institutions responsible for the management of the water bodies, the three riparian countries of Kenya, Tanzania and Uganda recognized the threats to the Lake Basin and decided to implement a joint Lake Victoria Environmental Management Project (LVEMP) for the management of the Lake Victoria Basin with financial assistance from the International Development Association (IDA) and Global Environmental Facility (GEF). LVEMP was initiated in 1994 with signing of a Tripartite Agreement between Kenya, Tanzania and Uganda, which provided for project planning and implementation. A comprehensive planning process by all relevant stakeholders resulted in the formulation of the Project with the aim of rehabilitating the degraded lake ecosystem so that it can support, in a sustainable manner the multiple human activities in the Lake Basin.

The LVEMP started in 1997 focusing on management and control of water hyacinth infestation; improvement and strengthening of fisheries research and management; improvement of the management of water quality; management of industrial and municipal effluents; conservation of soils and water, and management of agrochemical use within the region; capacity building through training, acquisition of equipment and other facilities; and involvement of local communities and other stakeholders in the implementation of the project to achieve ownership and sustainability.

Up to 2001, the LVEMP had made considerable achievements:

i. Water hyacinth infestation had been reduced by over 80%, although Kagera River, which drains Burundi and Rwanda, continuous to bring into the lake an estimated 0.8 ha of the weed daily. At the start of LVEMP in 1997, the weed covered an estimated 12,000ha of the Lake surface

ii. Recovery of indigenous fish species once feared extinct from Lake Victoria has been established and strategies to conserve and/or protect them made.

iii. Quantification of nutrient balance for the lake based has been made whereby atmospheric deposition accounts for 75% of phosphorus loading while municipal and industrial source accounts for only 6%.

iv. Inventory of all industries, shoreline settlements and urban centres in the basin, quantity of wastewater generated including the current capacity for wastewater treatment has been made as a basis for future management.

v. A total of 56 in-lake water quality monitoring stations have been established and regular monitoring of water quality is now done

vi. 'Hot spot' areas adjoining shoreline settlements including cities and towns, gulfs and bays receiving nutrients from agricultural land have been identified and strategies to improve of water quality in those areas, have been made and implementation started.

vii. Mapping of present land use/cover and soil erosion hazard in the Lake Basin has been accomplished and soil and water conservation mitigation measures initiated.

viii. Models have been developed for Lake Victoria Water Quality and for Buffering Capacity for Wetlands to be used as a tool for the Sustainable Management of the Lake Basin.

ix. The project has ensured ownership by local communities and sustainability of its activities through their involvement in project implementation.

x. LVEMP has facilitated human capacity building in all implementing institutions, which include 28 PhDs, 88 MSc, 3 BSc, 10 Diplomas and 1487 attended short courses and over 3500 participated in seminars/workshops

During Project implementation, a wealth of scientific data, information and knowledge has been gathered that could be shared with various stakeholders in defining trends in ecosystem and way forward for future measures for rehabilitation of Lake Victoria Basin. It is in this view that a Regional LVEMP Scientific Conference was held in December 2001 in Kisumu, Kenya where scientists working for LVEMP presented their research findings.

Flow of food materials among fish communities in Lake Victoria

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Abstract

Trophic relationships for different fish communities interacting in Tanzania waters of Lake Victoria were investigated in order to understand the flow of materials among those communities. Food chains, which usually start with photosynthetic green plants (algae, water hyacinth, Azolla, macrophytes, phytoplankton) and protists, obtain chemical energy from non-organic sources. Herbivores acquire materials from the plants and in turn carnivores obtain their food materials from juvenile fishes, zooplankton, Molluscs, insects and insect larvae. Bacteria (organisms of decay) obtain materials from dead plants and animals. The study has revealed that Speke gulf had the highest densities of secondary producers compared to other zones of the lake implying that there is more food available in the Speke gulf than in Mara, Mwanza or Emin Pasha gulfs. The abundance of *Lates niloticus* was the highest in the Speke gulf (190.4 kg/h). This suggests that there is plenty of food in the area. There seems to be a recovery of threatened fish species in the Speke gulf which has been used partially to explain why those food items predominate in stomach contents of *Lates niloticus*.

Key words: Fish communities; Food chain; Material flow; Pyramid of numbers.

Introduction

Organisms do not live alone but form part of a community in which the existence of each species and individual is affected by others. There is, not only interdependence of living organisms but also interaction with many other things outside and around them. In discussing communities in which numerous and diverse organisms live together, aspects of the environment that are inseparably related to all others are looked at more closely.

Native fish species, the haplochromines in particular, used to occupy all trophic levels and that they really played a major role in the flow of energy in the ecosystem. These species and others declined in the 1980's. However, overfishing, competition, predation and environmental degradation were identified as being the cause of the decline (Ligtvoet and Witte, 1991; Mugidde, 1993). But very recently, some of the native species even those that were thought to be extinct in the lake, have started to re-appear in the catches. This situation calls for the assessment of the trophic dynamics of the lake.

There is always flow of materials in a community which is cyclic. Materials are transferred from one species of organism to another, and that is the basic feature of a community as an organized association of different, interacting species. The sequence of flow through which materials pass is the food chain and it necessarily starts with photosynthetic plants or protists since they are the organisms that acquire energy from non-organic sources.

The aim of this work was to examine very closely on how the food items taken by different fish species relate to the quantity of food available within the environment.

Material and methods

Study area

Lake Victoria was divided into several zones. Within zones, study sites were established. In zone 1, the sampling sites were Shirati bay, Mori bay, Mara bay and Baumann's gulf. Within zone 2, sampling sites were Bunda hills, Bulamba, Ramadi and Magu bay. In zone 3, the sampling site was Kirumo/Entrance. Zone 4 included sites such as Luchiri, Chato bay and Nyamirembe. At each sampling site, samples of fish, zooplankton and phytoplankton were collected.

Samples of fish were collected using a stern trawler RV TAFIRI II with 150 Hp operating a trawl net 30mm cod–end mesh size in inshore waters in depths ranging between 3 and 20 metres. Each trawl operation took 30 minutes and on retrieval of the net, a sub-sample was taken. Fish of different species in the sample were counted. The total number of fish in the total catch was obtained by multiplying the number of fish in the sample by the number at which the catch was divided to obtain the sample. The density of fish in the area was obtained by dividing the number of fish in the total catch by the swept area and expressed as fish per m^2.

Macro-invertebrates were collected using an Eckman grab. Data collected was analysed to obtain average number of organisms per m^2.

A plankton net of 100µm mesh size with an opening of 25 cm in diameter, 1 metre long was used to obtain vertical haul zooplankton samples. In the laboratory, a sub-sample of 5mls was counted. The densities of individuals (individuals per unit area) of major taxa were recorded.

Phytoplankton samples were obtained by using a plankton net of 10 µm mesh. The samples were sub-sampled by means of a calibrated syringe, agitated, diluted and introduced into a 2 ml Sedgewick sedimentation chamber. Samples were examined under an inverted microscope at 400x magnification.

Results

Figs. 1, 2, 3 and 4 show pyraqmid of numbers at different trophic levels in zone 1, 2, 3b and 4, respectively. The Speke gulf is the most productive area followed by Mara, Emin Pasha gulf and Mwanza gulf in decreasing order in productivity. In this study, phytoplankton densities for different zones were not quantified due to technical problems. However, the group appears at the bottom of the pyramids as primary producers. Primary producers represented by phytoplankton, were collected but could not be quantified.Primary consumers were represented by zooplankton and some invertebates. Secondary consumers were represented by zooplanktivorous and *Rastrineobola argentea*.Tertiary consumers included all carnivorous fish, which are *Lates niloticus,* *Schilbe intermedius, Brycinus jacksonii, Brycinus sadleri, Synodontis victoriae* and *Clarias gariepinus*.

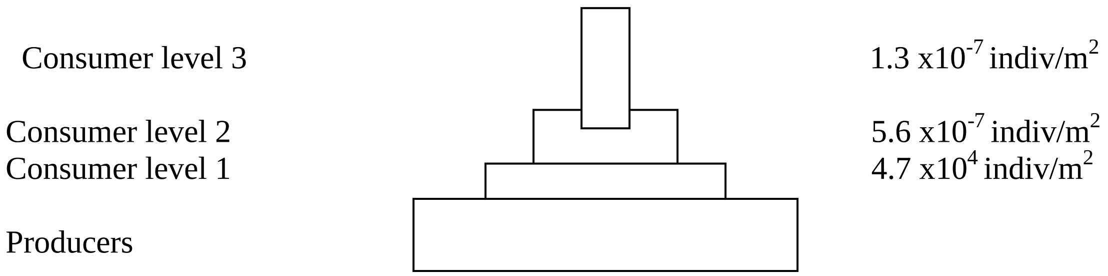

Fig. 1: Pyramid of numbers for Mara zone.

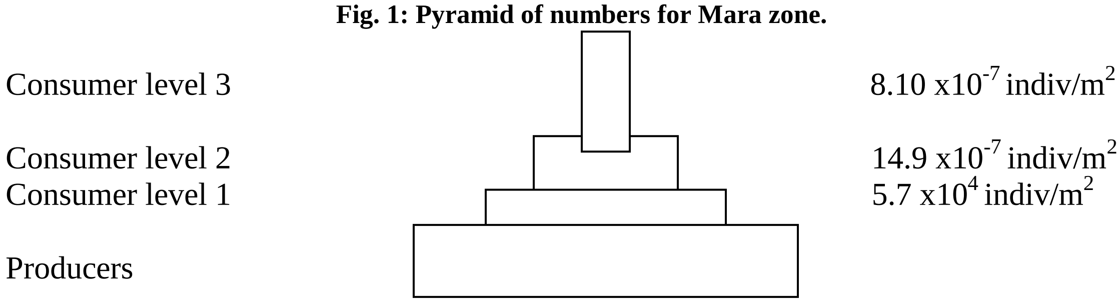

Fig. 2: Pyramid of numbers for Speke gulf

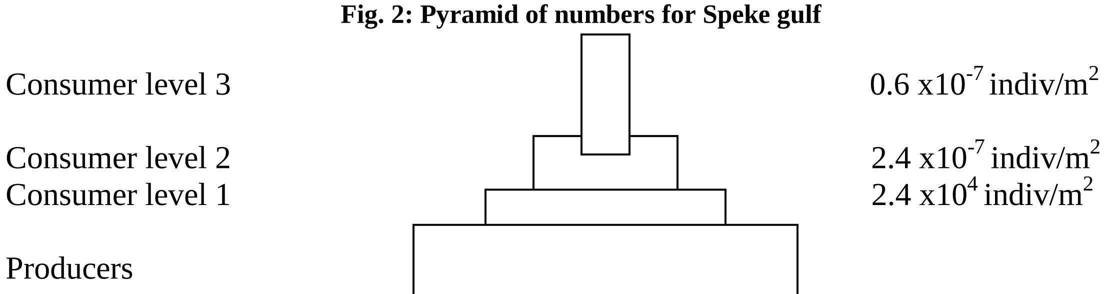

Fig. 3: Pyramid of numbers for Mwanza gulf .

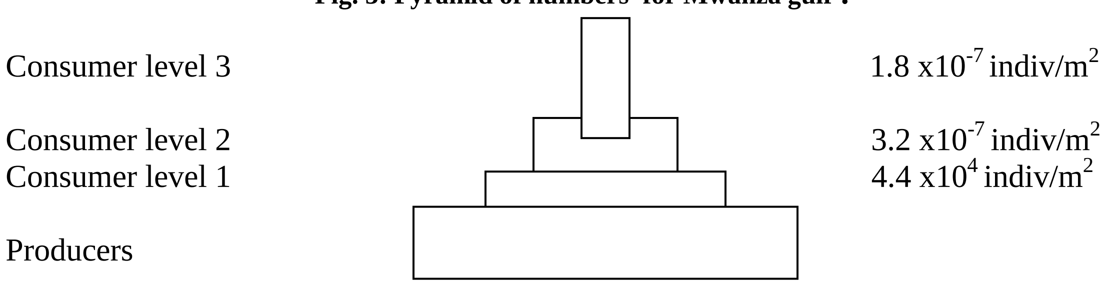

Fig. 4: Pyramid of numbers for Emin Pasha gulf.

Discussion

The Speke gulf had the highest densities of secondary producers compared to other zones of the lake implying that there is more food available in the Speke gulf than in Mara, Mwanza or Emin Pasha gulfs.

The abundance of *Lates niloticus* was the highest in the Speke gulf (190.4 kg/h). This suggests that there is plenty of food in the area.

Lates niloticus prefers to feed on haplochromines, *Rastrineobola argentea*, *Caridina nilotica* and on other fish species but changes its diet depending on the availability of the food item. These food items are shared with other carnivorous fish.

The recovery of the threatened fish species in the Speke gulf could have been a reason as to why those food items predominate in stomach contents of *Lates niloticus*. The predators normally tend to look for those food items that are abundant in order to conserve energy.

Organisms pass on to others less energy than they receive. When a herbivore eats a plant, it receives chemical energy, but the energy received is much less than the energy that the plant received from the sun. The organisms of decay end the sequence by passing on the materials of life in forms that are utilizable by other organisms but they practically complete the dissipation of energy in the community.

Smaller animals are generally found to be more numerous than larger ones and this has been revealed in the pyramid of numbers. Predaceous animals generally eat animals smaller than themselves. Most taxa of Macro-invertebrates are prey items of fish. Gastropoda snails are the food source of *Protopterus aethiopicus, Synodontis victoriae*, *Barbus altinalis*, *Lates niloticus* and the haplochromines which are normally smaller than the predator (Corbet, 1961; Hoogerhoud, 1986). The Chaoborid and Chironomid larvae are major food sources of insectivorous and zooplanktivorous haplochromines (Goldschmidt *et al*., 1990) and *Odonata* nymphs is the food source of *Lates niloticus* (Hughes, 1986; Ogutu-Ohwayo, 1990). The predators are usually larger and fewer than their prey and they require more food than a small one, and so have to monopolize more territory in order to survive as there is more food available for small than large animals in any given area.

Principles of cycles of materials, energy transfers and food chains have important implications for the abundance and activity of life of living organisms at any one place and time. All the energy and the greatest part of the materials in all living organisms must pass through green plants. The total activity of life, the flow of energy through all living organisms in the lake can proceed no faster than the fixing of that energy by photosynthesis. Photosynthesis can proceed no faster than the inflow of radiant energy from the sun.

Limitation of vital activity by the budget of available materials of nitrates, phosphates and silicates are strong and may be quite obvious in particular locations. Along the shores and river mouths, the areas are very productive compared to other areas farther out in the lake where nitrates and phosphates are rapidly utilized in upper levels of water where photosynthesis occurs. In deeper levels of water, dead organisms sinking to these waters are decomposed by bacteria and may be returned to sunlit surface waters by rise through currents.

The fluctuations of the abundance of diatoms is another limitation of material and energy budgets. Since diatoms regardless of their small size are the most important photosynthetic organisms of the lake and the whole rich life of the lake community changes with their fluctuation.

Conclusion

The study has revealed that Speke gulf had the highest densities of secondary producers compared to other zones of the lake implying that there is more food available in the Speke gulf than in Mara, Mwanza or Emin Pasha gulfs. The abundance of *Lates niloticus* was the highest in the Speke gulf (190.4 kg/h). This suggests that there is plenty of food in the area. There seems to be a recovery of threatened fish species in the Speke gulf which has been used partially to explain why those food items predominate in stomach contents of *Lates niloticus*.

Recommendations

Although the flow of food materials in fish communities of Lake Victoria is a continuous process, several other research areas need to be studied so that food materials and energy transfers can be correlated with fish stocks of the lake.

i. There is need to estimate the biomass of fish stocks, zooplankton and phytoplankton.
ii. Studies on physico-chemical characteristics of the lake should be conducted alongside biological studies.

Acknowledgement

The authors would like to extend their gratitudes to Lake Victoria Environmental Management Project Secretariate for funding this study, the Director General of TAFIRI for permitting them to participate fully in this project.

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The biology, ecology and fishery of *Oreochromis esculentus* in the Lake Victoria Basin

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Abstract

Oreochromis esculentus an indigenous tilapiine species in Lake Victoria has become extinct due to a number of factors. These include, introduction of a more competitive species (*Oreochromis niloticus*), eutrophication and over exploitation through gill-nets. *Aulocosira* an important food item for the species was displaced by the blue-green algae that were less nutritive. The species has however remained in the satellite lakes where in some cases it supports the fisheries of the riparian communities. The paper reviews some aspects of distribution, feeding and reproduction of *Oreochromis esculentus* in selected satellite lakes.

Keywords: Indigenous species, satellite lakes, eutrophication, exotic species, phytoplankton.

Introduction

The early gill-net fishery in Lake Victoria was based on *O. esculentus* and *O. variabilis* (Graham, 1929). With time, the fishery started to decline due to a number of factors such as intensive exploitation by deployment of efficient and increased gill-net fishery, and introduction of non-native tilapiines that performed better than the native species. These included *Oreochromis niloticus*, *O. leucostictus* and *T. zilii*. The introduction of these alien species further suppressed the survival of *O. esculentus.* The introduced species being competitively superior gradually eliminated the native *O.esculentus* due to unequal sharing of limited ecological requisites. (Fryer and Iles, 1972).

In Lake Victoria, the fish was confirmed to water less than 20m deep and was most abundant in sheltered gulfs and bays where the lake bottom comprised of soft algaceous mud. However in Satellite lakes, the species is confined to both inshore and offshore areas. In the main lake, the species fed essentially on phytoplankton (Graham, 1929; Worthington, 1929; Fish, 1955; Lowe, 1956). However, insect larvae and planktonic crustaceous could be part of diet of young fish. Greenwood (1974) recorded most of the fishes to be sexually mature at a length of 25 to 26 cm, and the modal adult size to be from 30 – 32cm.However cases occurred when specimen ranging between 40-50cm long could be caught particularly in the southern waters of Lake Victoria. It is of wide distribution in satellite lakes where it is still unknown as to whetrhe the species is indigenous or has been introduced.

O. esculentus once a delicacy of the riparian communities is completely lacking in L. Victoria. The surveys that have been going on in the catchment of L. Victoria, revealed that *O. esculentus* is occurring in a number of isolated water bodies. These are not only caught through sport fishing but in some cases the species form a big fishery that support the riparian communities like at Lake Burigi. The paper reviews the distribution of the species, the fishery in selected satellite lakes, food and some aspects of reproduction.

Materials and methods

Satellite lakes within the Lake Victoria basin were visited once every four months in which case samples of *O.esculentus* were collected from the catches made by the fishermen. However, a number of specimen were independently caught using a set of nets ranging between 2.5 mesh to 8.75cm at 1.25 interval. Though *O.esculentus* is of wide occurrence in many ponds and other small water bodies in the basin, the species is only found in exploitable levels at Lakes Malimbe Ikimba and Burigi where samples for detailed analyses of lengths, weights and gonads of individual fishes were taken from.

At each Lake, samples from either the fishermen or the independent fishing by the author were analyzed for weight, length, and gonad maturity stages. For the analysis of food item consumed, samples were stored in formalin and later in alcohol for further analysis.

Analysis of the modal lengths, lengths at 50% maturity and length weight relationships for the fishes caught at the three lakes of Malimbe Burigi and Ikimba were made to provide information on the appropriate mesh for the exploitation of the species. Also the gut contents were analyzed to investigate the food consumed by the species.

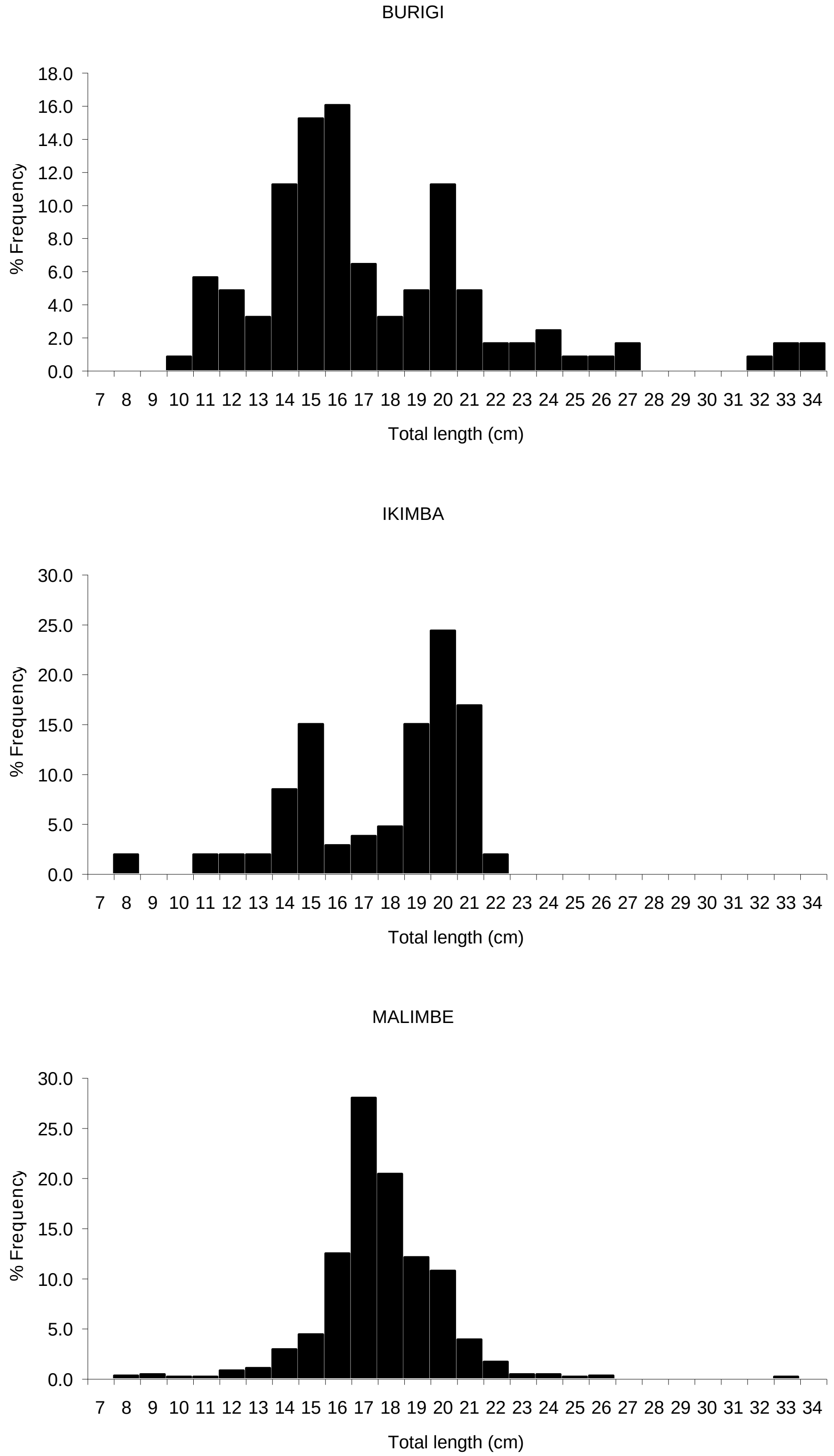
Results

Distribution

Although *O.esculentus* is indigenous to Lake Victoria, it has not been possible to catch the fish in the lake. However, the species has been found in satellite lakes, rivers and floodpools in varying amounts and in some lakes, the species is commercially exploited and contributes to the fishery in the respective lakes. For instance, the contribution by weight in some lakes have been recorded as follows; Lake Ikimba 79.4%, Lake Malimbe 72.1%. Lake Burigi 44.7%, Lake Kubigena 8.2%, Lake Kirumi 2.4%, Lake Katwe 2.2%. The size range of the individual fish varied from one lake to the other. For instance at Lake Burigi the size structure of the exploitable population ranged from 15-33cm. The distribution of exploitable sizes at Lake Malimbe varied between 7-30cm, For Lake Katwe the sizes ranged between 11-29cm. At Lake Ikimba the size range was 7-21cm.

Fig. 1 shows the distribution pattern of the exploitable part of the population at lakes Burigi, Ikimba and Malimbe. In Lake Burigi the fishermen deploy gill-nets of mesh sizes ranging between 50.8 – 88.9 cm (2-3 ½”). A prominent peak exists at 16 cm total length. From Fig 2, the length at 50% maturity for the male and females is between 16.50cm and 16.58 cm, respectively. It becomes obvious that the fishery is exploiting much of the breeding population without providing room for the young population to breed. The fishery independent data collection with gillnet ranging from 38.6 –88.9 cm (1.52” -3.5”) depicted progressive modes indicating that although the species is a continuous breeder, modal peaks are associated with different mesh sizes (Fig.3).

Fig.1 Length frequencies of the exploited part of the population



At lake Ikimba, the peak for the exploited part of the population was observed at 20cm. The lengths at 50% maturity for both males and females was 16.23 and

16.65cm respectively Figs.1 & 2. The average catch per boat is below 2kg. At lake Malimbe where *O.esculentus* comprise over 70% of the fish landings, the mesh sizes deployed by the fishermen is 7.5cm. The exploited part of the population occurred with a peak of 17cm. However, the length at 50% for male and female occurs at 17.51 and 18.56 cm, respectively.

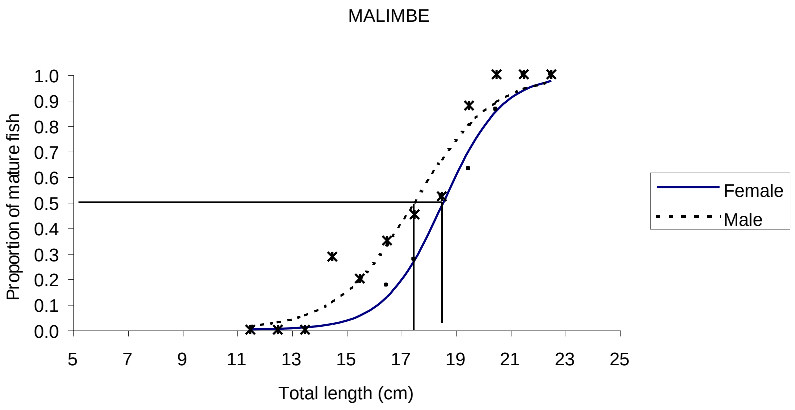
O.esculentus is essentially a phytoplankton feeder. A list of food items is shown in Table1. below.

Table1: A list of phytoplankton species found in the stomachs of *O.esculentus*

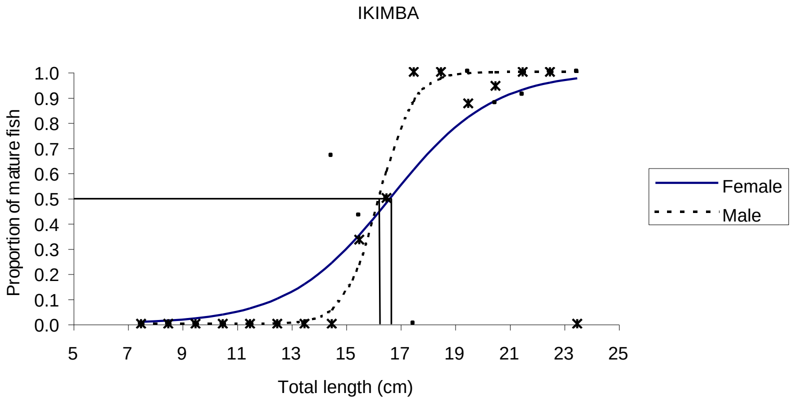
Chlorophyceae (Green algae)	**Cyanophceae** Blue-green algae)	**Bacillariophyceae** (Ditoms	**Xanthophycea** (Yellow-green algae)	**Rhodophycea** (Red algae)
Ankistrodesmus *Botryococus* *Coelastrum* *Microcystis* *Tetraedon* *Scedesmus* *Sprirogyra*	*Anabaena* *Microcystis* **Lynbrya**	*Aulocoseira* **Navicular**	**Botrydium**	*Porphridium*

Aulocoseira, *Botryococus* and *Porphyridium* have been found in large quantities suggesting their relative importance in the diet of the species. Higher plant materials and small quantities of other phytoplankton materials like *Tetradon* sp.*Chlorella, Oocyst* have also been found in small quantities in the stomachs of *O.esculentus*, *Chrolophycea* items were numerous. *Botryococus* appeared with very high frequency particularly at Lake Katwe

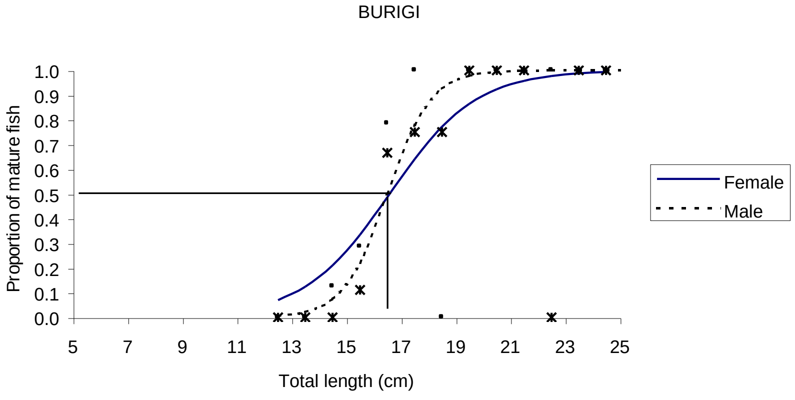
Fig. 2 Maturity ogives for O. esculentus from 3 satellite lakes



L_{50}	
Female	Male
18.56	17.51

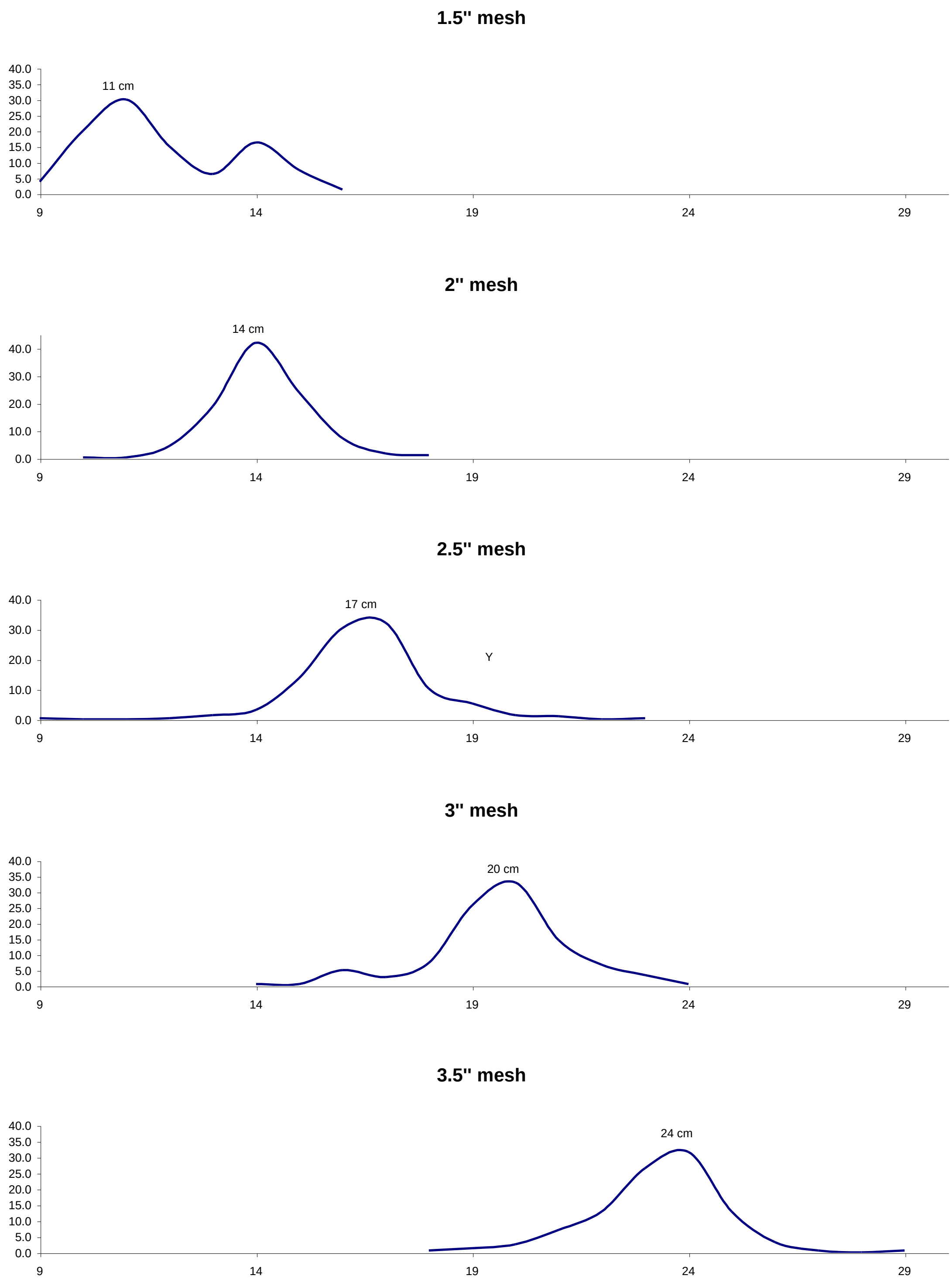


L_{50}	
Female	Male
16.65	16.23



L_{50}	
Female	Male
16.58	16.50

Fig.3 Mesh selectivity for O.esculentus in Lake Burigi



Discussion

In Lake Victoria, *O. esculentus* fed on planktonic material particularly the diatoms (Fryer and Iles, 1972; Lowe-Mc-Connel 1956). Stomachs of adult specimen comprised about 48.7% *Aulocoseira*.

Silicon conservation that is vital for phytoplankton growth, is thought to have been adversely affected due to increased inputs of phosphorus and sedimentation of silicon. The growth of *Melosira (Aulacoseira*) which was the main food of *O. esculentus* largely depended on silicon. This resulted in changes of dominance of *Aulacoseira* to *Nitzchia*. The phytoplankton population changed to dominance of cynobacteria that are low in energy content and hence poor food source (Lampert, 1981; Harney, 1987). This decrease in *Aulocoseira* may have contributed to disappearence of *O. esculentus* in Lake Victoria

In a given environment, the sexes are known to mature at the same time and are known to grow at the same rate. (Lowe, 1956; Garrod, 1956). The sizes at first maturity ranged between 20-21 cm. The sexual maturity in both sexes occurred at lengths of 25-27 cm TL (Graham, 1929; Greenwood, 1966). Sizes at first maturity in the early 1950's was 19-23 cm TL and 50% at 22 – 28 TL (Lowe-McConnel, 1956; Fryer and Iles, 1972). In the present situation the 50% maturity in all the lakes visited ranged between16.23 to18.58.cm indicating that either the conditions in the satellite lakes might be limiting or the heavy exploitation has suppressed the growth of the species. The prevailances of low mesh sizes of gill nets deployed in the satellite lakes remain a threat and may need revisiting. There is no baseline data on catches of satellite lakes to compare with the present size structure of fish caught but the proportion of fishes caught in relation to 50% maturity indicates sign of overexploitation. At Ikimba both male and female had L50 of 16.23 and 16.65 cm, respectively. The exploited population had a mode of 20 cm exploited by gill-nets of 7.5cm.

The description of the feeding mechanism of *Oreochromis* was based on *O. esculentus.* Other researchers (Fish, 1951; 1955; Lowe-McConnel, 1956; Welcome, 1967; Bailey, *et al.,* 1978) confirmed the species to be a planktonic feeder using the mucus trap mechanism with the action of the pharyngeal teeth. The species was non-selective in as far as the food organisms are being retained by this method, but is selective in that the gut contents analyzed comprised of diatoms Gee and Gilbert, (1967). In the satellite lakes *O.esculentus* has remained a phytoplankton feeder. The food constituent and pattern of selection for the species differs depending on the availability and location. But selectivity has biased towards feeding on *Aulocoseira, Botryococcus* and *Porphridium.*

Conclusion

Ecological aspects and survival of *O. esculentus* in Lake Victoria may be attributed to some environmental changes taking place in the lake. The species being a phytoplankton feeder may have been affected by the eutrophication resulting from an increase in nutrient drainage especially phosphorus and nitrogen into Lake Victoria. The source of nutrient being the atmospheric deposition and runoffs from the catchments.

Silicon conservation that is vital for phytoplankton growth, is thought to have been adversely affected due to increased inputs of phosphorus and sedimentation of silicon. The growth of *Melosira (Aulacoseira*) which was the main food of *O. esculentus* largely depended on silicon. This may have resulted in changes of dominance of *Aulacoseira* to *Nitzchia*. The phytoplankton population changed to dominance of cynobacteria that are low in energy content and hence poor food source. This decrease in *Aulocoseira* may have contributed to disappearence of *O. esculentus* in Lake Victoria.

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Conservation and improvement of the stocks of the originally most important Lake Victoria tilapiine, *Oreochromis esculentus*, Graham 1929

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Abstract

The tilapiine fish species *Oreochromis esculentus* was endemic to only lakes Victoria and Kyoga, and was the most important commercial fish species in these two lakes. This species started to decline steadily after the introduction of modern fishing technology until 1960 when the last reserves were depleted and is now apparently extinct from these two lakes. This situation prompted a search of water bodies in the two basin lakes for evidence of its possible survival in some localities. Therefore a study of four satellite lakes in the Lake Victoria basin (Mburo, Kachera, Kayanja and Kayugi) and three (Nabisojjo, Kawi and Lemwa) in the Kyoga basin were investigated for the presence of *O. esculentus* using an experimental fleet of gill nets to try and assess the populations that would be useful in conservation efforts. *O. esculentus* were relatively most abundant in Lake Nabisojjo (58.1 %), followed by Kayanja (22.6 %), Lemwa (14.2 %), Mburo (6.3 %), Kachera (5.9 %), Kawi (1.7 %) and Kayugi (1.4 %). The fish examined was 7.5- 38.7 cm total length (tl) with a modal size of 16-21 cm tl compared to records of 30-32 cm in Lake Victoria. The largest fish was from Lake Kayugi 38.7 cm, followed by Kachera (28.5 cm), Kayanja (28 cm), Nabisojjo (26.7 cm), Mburo (26 cm) , Kawi (25 cm) and Lemwa (24.5 cm) tl. The fish had an overall mean condition factor k of 1.77±0.02 as compared to historical records of 2 in Lake Victoria. Fish from Lakes Kawi and Kachera had the highest k (1.92± 0.02) followed by Kayugi (1.90 ± 0.03), Lemwa (1.78 ± 0.03), Mburo (1.71 ± 0.01), Nabisojjo (1.65±0.02 and Kayanja (1.50 ± 0.02). Diatoms were previously recorded as the best food for *O. esculentus*. Blue green algae especially *microcysts,* were the most dominant item ingested in Lakes Kachera, Mburo and Lemwa. *Planktolyngbya* was most important in Kayanja, while the diatom *aulacosira* was most important in Kayugi and Kawi and detritus in Nabisojjo. Size at first maturity was 20.5 cm tl in Kayugi, 19.4 cm in Nabisojjo, 17.2 cm in Lemwa, 16.8 cm in Mburo and Kachera, 15.6 cm in Kayanja and 12.5 cm in Kawi. Originally, *O. esculentus* matured at 26-27 cm in Lake Victoria and 21 cm tl in Kyoga. There were more males than females (1:0.83) as was the case in historical records. Sex ratios were in Lake Mburo 1:1.1, Kachera 1:0.9, Kayanja 1:0.85, Kayugi 1:0.97, Nabisojjo 1:0.69, Kawi 1:0.52, and 1:0.75 in Lemwa. Fecundity was directly proportional to size of *O. esculentus* and the highest was (963±148 eggs) in Lake Kayugi, followed by Lemwa (532 ± 18), Kachera (518 ± 24), Kawi (507± 32), Kayanja (468 ± 184), Nabisojjo (429±11) and Mburo (341±19). *O. esculentus* from Lake Kayugi where diatoms (*aulacosira*) dominated in their diet were the largest and had the highest condition factor. This indicates that diatoms were important food and is valuable in the survival of *O. esculentus*. On this basis, Lake Kayugi is the best source of *O. esculentus* either for restocking or for captive propagation. However, with the shift of algal communities to blue greens the capacity for *O. esculentus* to assimilate blue greens should be investigated further.

Keywords: *Oreochromis esculentus*, tilapiines, Lake Victoria, Lake Kyoga, satellite lakes.

Introduction

Oreochromis esculentus Graham, (1929) is endemic to lakes Victoria and Kyoga and a few satellite lakes in the basins of these lakes (Ogutu-Ohwayo, 1993). Up to the 1900s *O. esculentus* together with *O. variabilis* were the most important commercial fish species in these two lakes. Lake Victoria then contained large stocks of *O. esculentus* Graham, (1929). During the period 1905 to 1916, when gill nets were introduced into different parts of Lake Victoria, coupled with the growth of urban centers and communication around the lake, fishing industry assumed a commercial role with *O. esculentus* as one of the main target species (Mann, 1969; Miles and

Keenleyside, 1991; Balirwa, 1992). From 1930s to 1950s the catch dropped and the fish became smaller due to increased fishing pressure (Fryer and Iles, 1972; Fryer, 1973) and increasing use of small mesh sized gill nets (Witte and van Dansen, 1995). This made *O. esculentus* one of the most threatened fish species and deprived the people who depended on it for food and employment.

In Lake Victoria, Graham, (1929) recorded *O. esculentus* of 30 cm tl in Kavirondo gulf and 31 cm tl in the open lake. According to Greenwood, (1966), the modal adult size was 30-32 cm tl, although specimens 40-50 cm tl long were caught in the southern waters of Lake Victoria (Graham, 1929). In Lake Kyoga *O. esculentus* never exceeded 26 cm tl (Worthington, 1929).

Overall weight was proportional to the cube of the length ($100w = 2l^3$) and the condition factor **k** was **2** in Lake Victoria (Graham, 1929).

In Lake Victoria, *O. esculentus* fed on planktonic material collected from suspension (Fryer and Iles, 1972) especially diatoms (Fish, 1951; 1955; Lowe-McConnell, 1956; Welcomme, 1967; Bailey *et al.*, 1978). Schools of *O. esculentus*, followed concentrations of diatoms in the lake (Gee and Gilbert, 1967) suggesting that this was its preferred food item, although maximum growth in aquaria could be obtained on an unnatural diet of chopped worms S*tuhlmannia* spp., (Cridland, 1964). *Aulacosira* was usually the most abundant item in the gut contents and comprised 48.75 % of the total cells present in all fish stomachs (Payne, 1971).

The size at initial breeding seemed to be determined by the environment. In aquaria, breeding occurred at 10 cm tl, at the age of 5 months (Garrod, 1956). In a pond at Korongwe, Lowe (1955) found that both sexes had bred at 16-19 cm when they were less than seven months. In Lake Victoria, the smallest mature *O. esculentus* was 20-21 cm. Sexual maturity in both sexes occurred at a length of 25-27 cm tl (Graham, 1929, greenwood, 1966). The size at first maturity (in Lake Victoria) in the early 1950s was 19-23 cm tl, and 50% at 22-28 cm tl (Lowe-McConnell, 1956; Fryer and Iles, 1972). At the end of the 1950s the smallest mature fish were 18-20.5 cm tl and 50% maturity was at 22.5-23.8 cm tl in Smith Sound (Tanzania). In the Tanzanian waters of Lake Victoria it was 28 cm tl, in the Kavirondo Gulf (Kenya) 22 cm tl, in Jinja area 25-26 cm tl and in Sesse island 28 cm (Fryer and Iles, 1972). *O. esculentus* is a female mouth-brooder, without well-marked spawning seasons. Highest breeding activity occurred between September and May (Greenwood, 1966), although breeding fishes were found throughout the year (Trewavas, 1983). Females could have a succession of 3 or more broods in a spawning period and fewer eggs were produced in the last brood of a series than the first. The average interval between broods in *O. esculentus* in aquaria was 2 months, 28 broods being recorded from 10 pairs in 23 months. The number of eggs produced increased with the size of the female, ranging from 324 eggs in a fish of 17 cm tl to 1672 eggs in one of 36 cm tl (Graham, 1929).

Because of its high economic value, and since O. esculentus is only endemic in the Victoria and Kyoga lake basins, it was one of the first fish species to be extensively studied in lakes Victoria and Kyoga. It's ecology and biology in Lake Victoria was investigated by Graham, (1929) and in Lake Kyoga it was investigated by Worthington, (1929). However, very little was known on *O. esculentus* in the satellite lakes where remnants of its population are still present. The purpose of this research therefore, was to gather information on the biological characteristics of this species in the satellite lakes and to compare the results with the historical records for lakes Victoria and Kyoga. These two lake basins have been sampled for comparison because they share a common evolutionary history, have similar native fish faunas (Graham,1929; Worthington, 1929) and have also had similar impacts by introduction of Nile perch, *Lates niloticus,* therefore, they can be considered to be similar for ichthyogeographical studies.

Materials and methods

The study was carried out on lakes Kachera, Mburo, Kayanja and Kayugi in the Victoria lake basin and lakes Nabisojjo, Lemwa and Kawi in the Kyoga lake basin. Sampling was done using three fleets of identical multifilament nylon gill-nets. Fish were measured for total and standard lengths (tl and sl) in centimeters, weighed in grams and recorded. The specimens were dissected and the stomach fullness, sex and maturity stage of the fish determined. Female gonads at maturity stage v and vi and stomachs which had any food were removed and preserved in 5 % formalin solution in separate numbered bottles. The stomach contents were allotted a number of points according to the scheme modified from Hynes (1950) and the food categories were rated in proportion to their relative percentage volumes as spread out in a petri dish or slide. The importance of each of the food items was obtained from these points by calculating the percentage relative importance of the food in the stomachs. All the eggs in the two gonads of an individual fish were counted and was taken as the 'absolute fecundity'.

Results

Relative abundance

A total of 2495 *O. esculentus* were examined. *O. esculentus* were most abundant (relative to the rest of the species caught per lake) in Lake Nabisojjo (58.1 %), followed by Kayanja (22.6 %), Lemwa (14.2 %), Mburo (6.3 %), Kachera (5.9 %), Kawi (1.7 %) and Lake Kayugi (1.4 %) as shown in Figure 1.

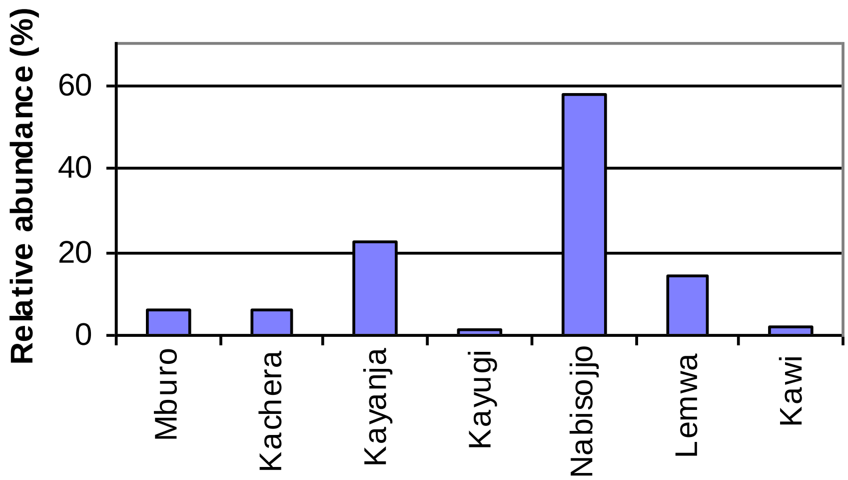

Figure 1. Abundance of *Oreochromis esculentus* in the sampled lakes in relation to other species

Length frequency distribution of *Oreochromis esculentus*

A total of 2495 fish were examined from all the sampled lakes. The number of fish examined in the different size groups is illustrated graphically as shown in Figure 2. The size range of *O. esculentus* examined in all the lakes was 7.7 cm to 38.7 cm tl. Most fish lay in the size range of 16-20 cm. The biggest fish (38.7 cm tl) was encountered in Lake Kayugi. In Lake Kachera, the range was from 7 cm to 28 cm tl; Lake Mburo 11 cm to 26 cm tl, Lake Kayanja, 7 cm to 28 cm tl; Lake Kawi, 14 cm to 25 cm tl; and Lemwa, 10 cm to 24 cm tl and Lake Nabisojjo 7.5 cm to 26.7 cm tl.

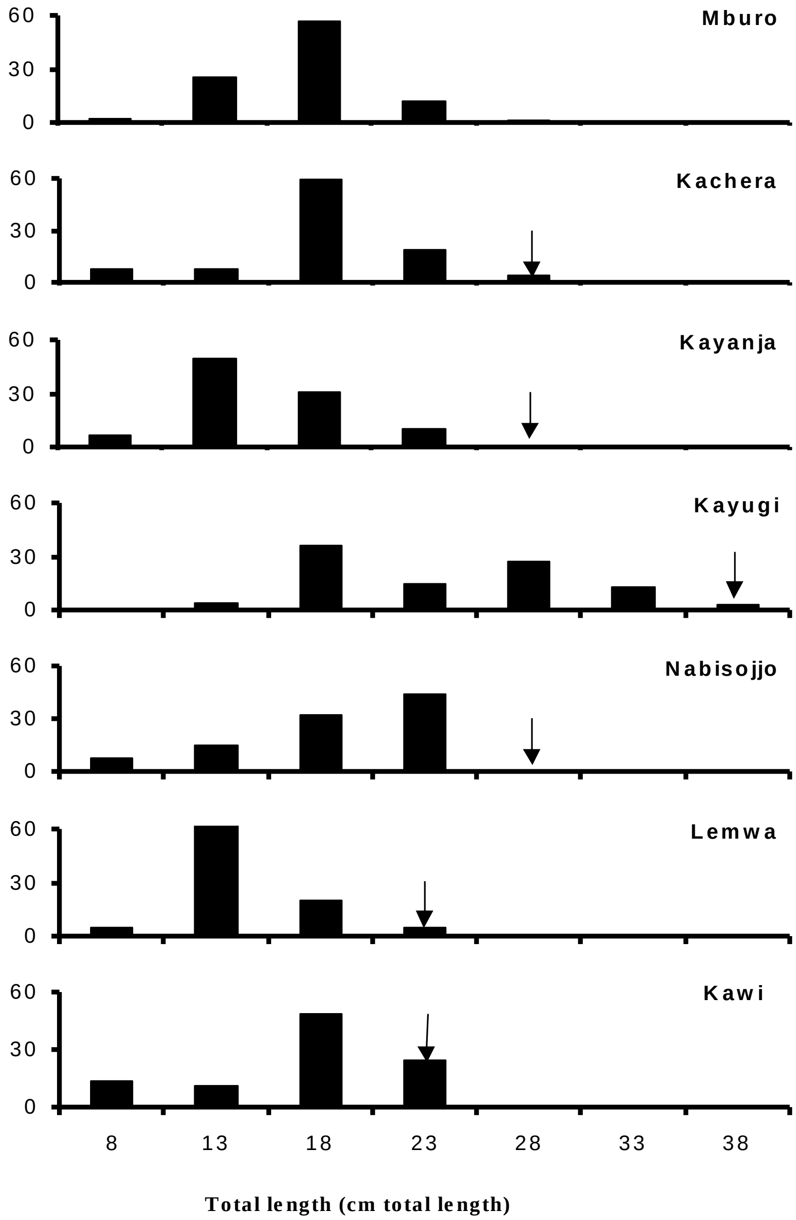

Figure 2. Length frequency distribution of *Oreochromis esculentus* sampled from the various lakes. Arrows show the largest fish encountered per lake.

Condition factor

On the overall the average condition factor k was 1.79±0.02 pooled data for all the sampled lakes. K factor was highest for *O. esculentus* from Lake Kawi (1.92 ± 0.02), followed by lakes Kachera and Kayugi, (1.89 ± 0.03/2), Lake Lemwa (1.77±0.03), Mburo (1.71±0.01), Lake Nabisojjo (1.65±0.02) and the smallest was (1.50 ± 0.01) from Lake Kayanja (Figure 3).

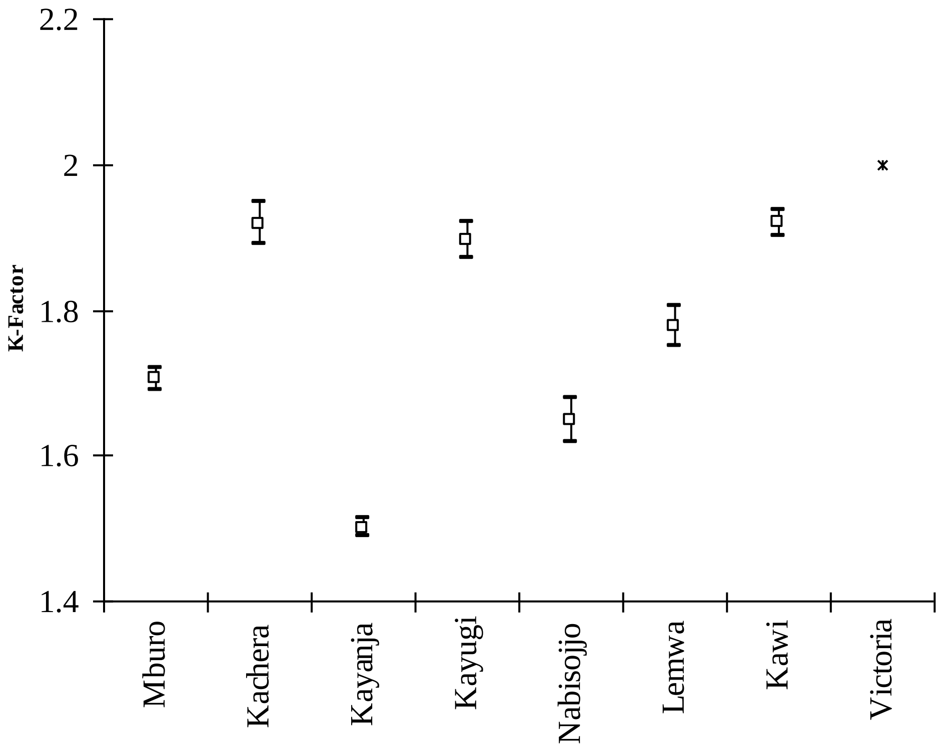

Figure 3. Comparisons of values of condition factor K of *Oreochromis esculentus* from the various sampled lakes

The tests using anova (single factor), showed no significant differences in the condition factor of *O. esculentus* between the sampled lakes, ($p=0.05$) as shown in Figure 3.

Food of *Oreochromis esculentus*

In total, 615 stomachs of *O. esculentus* were examined. 51 in Lake Mburo, 157 in Lake Kachera, 91 in Lake Kayanja, 16 in Lake Kayugi, 84 in Lake Nabisojjo, 118 in Lake Lemwa, and 98 in Lake Kawi. The most important food items overall were *microcystis* (28.7 %), followed by *aulacosira* (16.4 %) and *anabaena* (13.8 %). There was variation in the diet in the different lakes.

The food items were then grouped into their various classes as green algae (chlorophyceae), blue-green algae (cyanobacteria) and diatoms (bacillariophyceae). Figure 4 shows their percentage occurrence per lake. Most of the food items belonged to the genera chlorophyceae (6 species), while the rest (cyanobacteria and bacillariophyceae) contained one each. According to these groups the blue green algae were the most important overall (all lakes pooled together) 62.3 % followed by diatoms 16.4 % as seen in Figure 4.

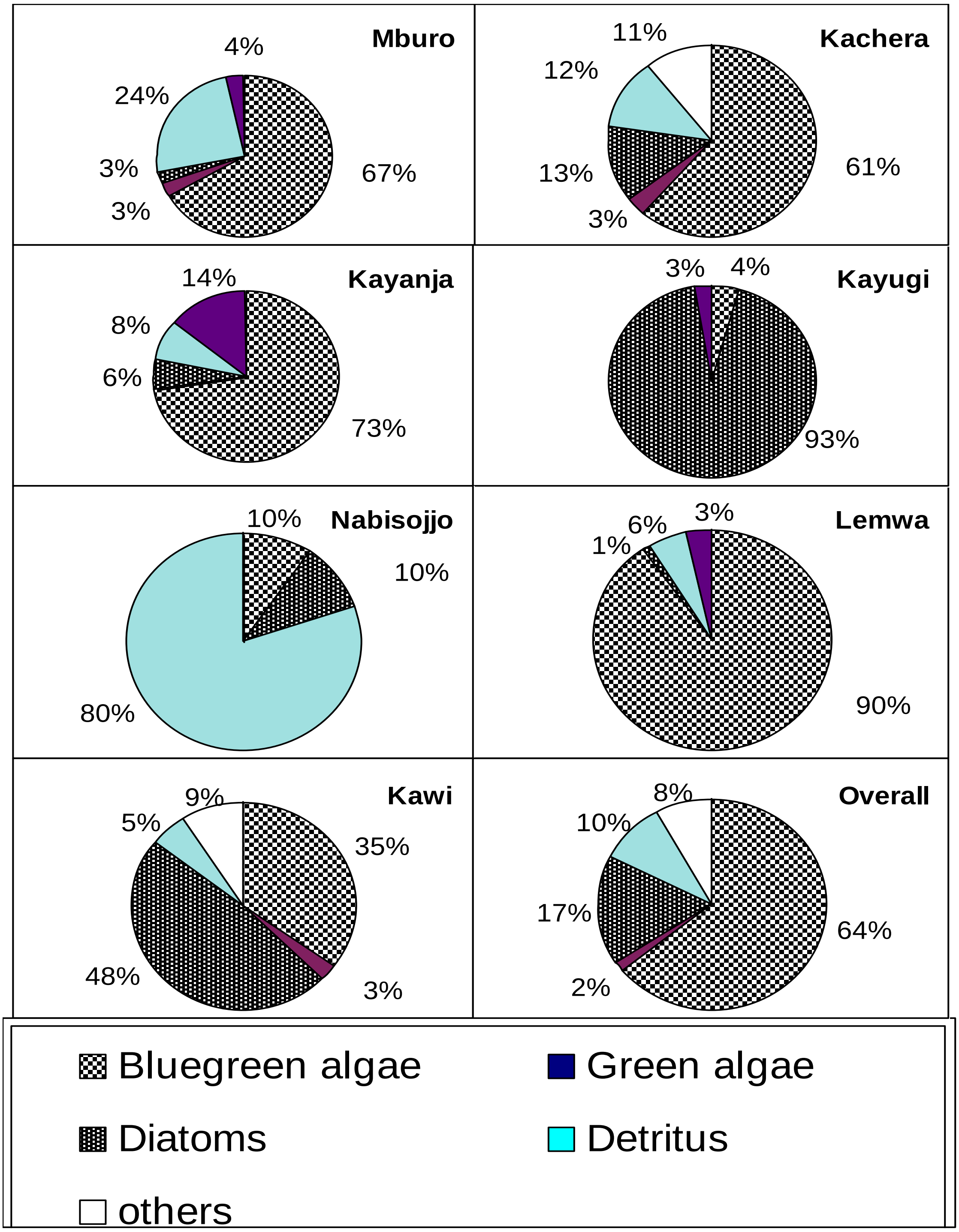

Figure 4. Percentages of the food categories encountered in stomachs of *Oreochromis esculentus*

Size at first maturity

There were variations in size at 50 % maturity of *O. esculentus* as shown in Table 1. Mid-classes were used in the graphical illustrations (Figure 5) which was used to estimate size at first maturity between the different lakes. In Lake Kayugi, 50 % maturity size was approximately 20.5 cm tl and was the highest, followed by Lake Nabisojjo 19.4 cm tl that of lakes Kachera and Mburo 16.8 cm tl and 15.5 cm tl in Lake Kayanja was the lowest as seen in Figure 5.

Table 1. Size at 50 % maturity of *Oreochromis esculentus* from the various sampled lakes

Lake	50 % maturity size (cm tl)
Mburo	16.8
Kachera	16.8
Kayanja	15.6
Kayugi	20.5
Nabisojjo	19.5
Lemwa	17.2
Kawi	12.5

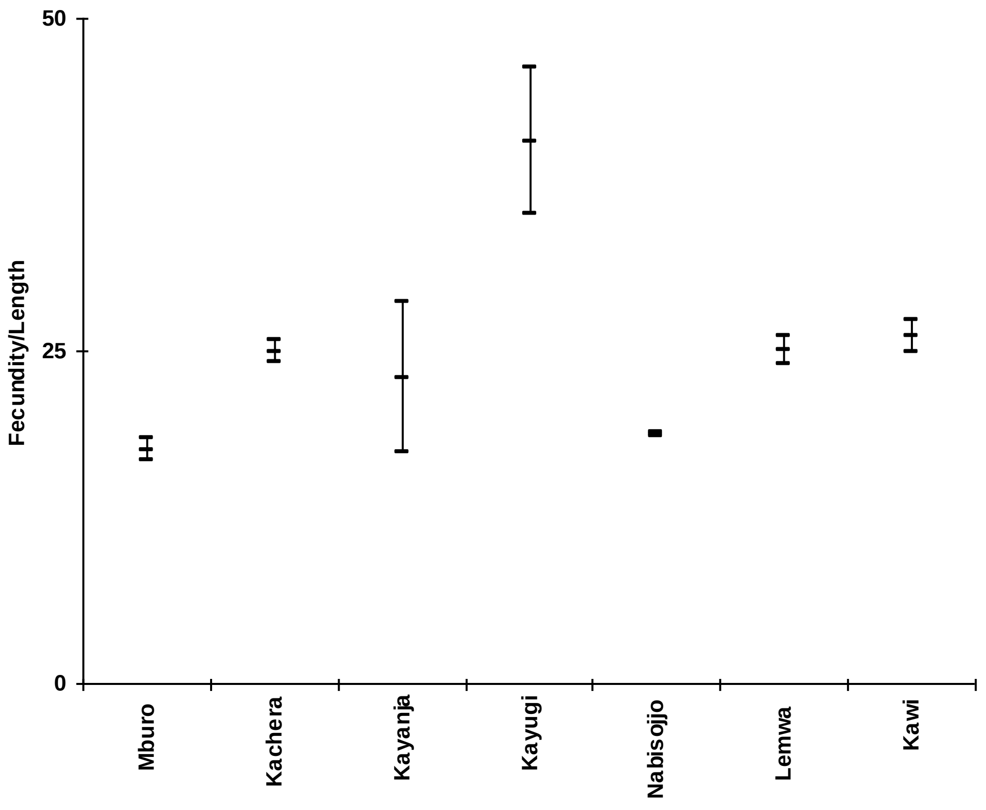

Figure 5. Comparison of fecundity per length (cm) of *Oreochromis esculentus* from different habitats

Sex ratio

Total counts of females per male for the sampled lakes were made as ratios of male: female (m:f). This was repeated for all the lakes (pooled together) and was established as the overall sex ratio of *O. esculentus* examined. On the overall, 1297 males and 1079 females were studied giving a ratio of m:f = 1:0.96. In Lake Kachera, the sex ratio was m:f = 1:0.9, Mburo m:f = 1:1.11. Kayanja m:f = 1:0.91, and Kayugi m:f = 1:0.97.

Fecundity of *Oreochromis esculentus*

One hundred twenty eight ripe gonads were examined from all the sampled lakes; Twenty six (26) gonads from Lake Mburo, 42 from Kachera, 6 from Kayanja, 3 from Kayugi, 29 from Nabisojjo, 9 from Lemwa and 13 from Kawi. A total egg count per fish was regarded as the absolute fecundity as shown in Table 2. The examined gonads were from fish ranging from 14.6 to 30.2 cm tl. The smallest number was 157 eggs in a fish of 14.6 cm tl from Lake Kayanja and the largest was 1364 eggs in a fish of 28 cm tl from Lake Kayanja.

Table 2. Means of absolute fecundity and length (± standard error) for the sampled lakes. The total number of gonads examined was included. (tl= total length, wt= weight, n= number of studied fish).

Means	Mburo	Kachera	Kayanja	Kayugi	Nabisojjo	Lemwa	Kawi
Fecundity	341±19	518±24	468±184	963±148	429±10.8	532±28.18	507±32.43
Length (cm) tl	19.3±0.65	20.6±0.5	18.1±2.1	24.6±5	22.9±0.2	21±0.66	20±0.7
Fec/leng ($f.cm^{-1}$)	17.5±0.82	24.9±0.84	22.9±5.65	40.7±5.48	18.7±0.2	25±1	26±1.19
Wt	132±8.07	181±12.4	129±69.6	390±169.9	206±5	190±16.58	159±13.5
No. **"n"**	26	42	6	3	29	9	13

Following literature conversion Ricker, (1971), a general power and linear curve of the relationship between absolute fecundity and size (length and weight respectively) of pooled data from all sampled lakes were drawn. A power curve for the fecundity-length relationship was;

$$F = 1.253l^{1.569} \qquad r^2 = 0.5146,\ n = 128 \qquad (1)$$

A linear curve for the fecundity-weight relationship was:

$$F = 1.6957w + 195.13 \qquad r^2 = 0.6483,\ n = 128 \qquad (2)$$

where F is the number of eggs, l the total length of the fish in cm and w the weight of the fish in gm.

The graphs showed that absolute fecundity was positively correlated with size.

Discussion

Originally, the native tilapiine *Oreochromis esculentus* was the most abundant and important commercial fish species on Lake Victoria but today, it is apparently absent in the main lakes of Victoria and Kyoga. However, remnants of these species are seen to have survived in some of the satellite lakes in these two lake basins but are not the most abundant where they occur. The size of the different populations has reduced from a modal size of 30-32 cm tl to the present modal size of 16-20 cm tl. There is also a reduction in the mean condition factor k from 2 in Lake Victoria to 1.77 in the sampled satellite lakes. *O. esculentus* was reported to be a phytoplankton feeder with a strong preference for the diatom *aulacosira* which used to be the most abundant food item in the diet. However, in the satellite lakes the blue-green algae especially the *microcystis* were the most dominant food item. This change in diet could explain the reduced species abundance, size composition, condition factor and size at first maturity. The apparently increased nutrient input in Lake Victoria (Hecky, 1993) was accompanied by higher blue-green algal biomass relative to that observed during 1960-1961. Such a shift in phytoplankton species composition might result in a lower efficiency of energy transfer to higher trophic levels, since the blue-green algae are generally considered a poor food source. There are practical considerations to be taken on the choice of the most suitable *O. esculentus* populations depending on the investigated ecological and biological aspects. The fishes that fed on the diatom aulacosira were the best, which shows that *aulacosira* is very important food of *O. esculentus* and occurs abundantly in Lake Kayugi.

Conclusions

Some conclusions and recommendations are proposed as follows:

- There was still *Oreochromis esculentus* in some satellite lakes.
- The population characteristics varied between the sampled lakes.
- Generally, there was a shift in the algal communities dominance from diatoms to blue greens and this could be a sign of environmental degradation.
- *Oreochromis esculentus* from Lake Kayugi where diatoms (especially *aulacosira*) dominated in the diet, were the largest, had the highest condition factor and reproduction potential. This indicates that diatoms were important food and valuable in the survival of *Oreochromis esculentus*.
- Lake Kayugi is being protected by traditional myths (e.g no boat is allowed on the lake except rafts; no drawing water from the lake using sooty saucepans etc).
- The lakes especially Kayugi should be protected from fishing malpractices.
- With the shift of algal communities to blue greens, further research should be done to investigate the capacity of *Oreochromis esculentus* to assimilate the blue greens.

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Some aspects of Nile tilapia *Oreochromis niloticus (L.)* population characteristics in Lake Victoria, Kenya.

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Abstract

Length frequency data collected from commercial landings were used to estimate growth parameters, mortality (*Z, F, M*), growth performance index (ϕ') and exploitation rate (*E*) in *O. niloticus* from the Nyanza Gulf of Lake Victoria, Kenya. The asymptotic length (L_∞) had mean (±S.D) of 58.78 ± 2.42 cm TL, *K* of 0.59 ± 0.05 yr^{-1}, *Z* of 2.16 ± 0.40 yr^{-1}, *M* of 1.00 ± 0.06 yr^{-1}, *F* of 1.12 ± 0.34 yr^{-1}, *E* of 0.51 ± 0.06 and ϕ' of 3.31 ± 0.04. Fifty percentage (L_{50}) entry into the fishery had a mean (±S.D) of 26.18 ± 12.50 cm TL.

A comparison with previous studies in the gulf indicates that *O. niloticus* is now caught at a lower mean size, *K, Z, M, F,* have increased and the fish is maturing earlier. These changes may point to a population under stress, but still the fish exhibits high growth performance (ϕ') and grows to a large size and if well manage high production can be attained. The study showed that the major threat to the *Oreochromis* fishery is overexploitation caused by use of illegal fishing methods leading to capture of immature fish and breeding fish.

The remedial measures to sustain the fishery include imposing ban on illegal fishing methods, limiting entry to the fishery, encouraging alternative livelihood and involvement of the community in fisheries management.

Key words: growth, mortality, recruitment, selection

Introduction

The Nile tilapia, *Oreochromis niloticus* (L.), which was introduced in Lake Victoria in 1950s, is the third commercially important fish after introduced Nile Perch, *Lates niloticus* (L.) and endemic pelagic cyprinid *Rastrineobola argentea* (Pellegrin) (Witte and Densen 1995; Othina and Tweddle 1999). Increase in *O. niloticus* is attributed to over fishing of endemic tilapiines thus reducing competition while swamps clearance could have increased it spawning areas (Welcomme 1967). The *O. niloticus* can also survive a wide range of pH, resists low levels of dissolved oxygen and feeds on a variety of food items (Balirwa 1998; Njiru 1999).

In Kenya waters of Lake Victoria *O. niloticus* is slow growing and majority of the fish caught is below the recommended 5 inches mesh size (Getabu 1994). Studies further show that the fishery is operating beyond maximum sustainable yield, indicating overfishing. This study was designed to study population parameters of *O. niloticus* using length frequency data in different locations in Nyanza Gulf of Lake Victoria, Kenya. The results are compared with previous studies to offer management strategies for the fishery.

Materials and methods

Study area

The Nyanza Gulf constitutes the major portion of Kenyan part of Lake Victoria, with an area of 1920 km^2, a length of 60 km and a width varying from 6 and 30 km (Fig 1). The gulf is shallow with a mean depth of 6 m and lies at an altitude of 1134 m above sea level. A description of the gulf is given by Okach and Dadzie (1988).

Sampling

Monthly length frequency data on *O. niloticus* were collected from July 1998 to December 2000 from commercial catches at five landing sites in the Nyanza Gulf of Lake Victoria (Fig. 1). The samples were representative of the stock from the outer, mid, and inner Gulf, *viz*, Dunga, Kendu Bay, Asembo Bay, Homa Bay and Luanda Gembe. Approximately two hundred specimens were randomly selected from commercial catches every month at each station and measured (total length (TL), nearest cm). The surface temperature was recorded for each station every month to determine the natural mortality coefficient.

Data analysis was based on length frequency distribution analysis. The Eletron Length Frequency Analysis (ELEFAN I and II) computer programs incorporated in FAO-ICLRAM Stock Assessment Tool (FISAT) (Pauly 1987; Gayanilo et al. 1996) were used to estimate population parameters. Data for each landing site was merged into a single file thus constituting a single ‘‘artificial year’’. The estimate of the growth parameters were based on the Von Bertalanffy growth formula (VBGF) expressed by the form:

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

Where, L_t is the predicted length at age t, L_∞ is the asymptotic length, K is a growth constant, t_o is the age the fish would have been at zero length.

Preliminary estimation of L_∞ was done by the Powell-Wetherall method and FISAT was further used to improve the quality of L_∞ and K (Pauly 1980). Total mortality (Z) was estimated using a length-converted catch curve. Natural mortality (M) was estimated from equation of Pauly (1980). This method consists of a plot of the natural logarithm of the number of fish in various age groups against their corresponding age. A regression analysis is done on the descending right hand arm of the catch curve, and Z estimated as the negative slope. The coefficient of natural mortality (M) was estimated following Pauly’s empirical formula (Pauly 1980), linking natural mortality with the von Bertalanffy parameters, K (yr^{-1}), L_∞ (cm) and the mean annual temperature (T ^oC) of the water in which the fish stock lives (in this case 25 ^oC): i.e.,

$$log_{10}(M) = -0.0152-0.279* log_{10} L_\infty + 0.6543 \, log_{10} K + 0.463 \, log_{10} T$$

The fishing mortality (F) was computed from the relationship $F = Z\text{-}M$, while the exploitation rate (E) was calculated from the relationship $E = F/Z = F/(F + M)$. The growth performance index (ø) was computed according to Pauly and Munro (1984):

$$ø = log_{10} K + 2\ log_{10} L_{\infty},$$

where, K is the growth constant (yr^{-1}) and L_∞ is the asymptotic length.

Gear selection was estimated by backward extrapolation of the catch curve, thus estimating the number of juveniles, which ought to have caught had it not been for incomplete selection and recruitment. To obtain probabilities of capture, the number of fish in each length class caught were divided by the expected numbers (Pauly et al. 1984). A plot for probability of capture by length was obtained from the backward extrapolation of the right, descending arm of a catch-curve, and calculating the number of fish that would have been caught had it not been for selection and incomplete recruitment. Recruitment pattern was obtained by projection of length axis of the available length-frequency data.

Table 1. Asymptotic length (L_∞), growth curvature (K), and growth performance index (*ø)* of *O. niloticus* artisanal catches from Nyanza Gulf, Lake Victoria, Kenya.

	Powell Wetherall L_∞(cm)	ELEFAN L_∞(cm)	K (yr^{-1})	(ø)
Dunga	56.07	57.00	0.56	3.26
Kendu Bay	58.83	58.00	0.55	3.27
Asembo Bay	58.59	59.80	0.59	3.32
Homa Bay	57.31	56.60	0.68	3.34
Luanda Gembe	60.86	62.50	0.58	3.36
Mean ± SD	58.33±1.79	58.78±2.42	0.59±0.05	3.31±0.04

Table 2 Total mortality (Z), Natural mortality (M), fishing mortality (F) coefficient, and exploitation rate (E) of *O. niloticus* artisanal fishery from Nyanza Gulf of Lake Victoria.

Station	Z	M (yr^{1})	F (yr^{1})	E
Dunga	2.06	0.97	1.09	0.53
Kendu Bay	1.77	0.95	0.82	0.46
Asembo Bay	1.03	0.99	1.03	0.51
Homa Bay	2.81	1.10	1.71	0.61
Luanda Gembe	1.93	1.10	1.71	0.61
Mean±SD	1.92±0.64	1.00±0.06	1.12±0.34	0.52±0.06

Results

The mean (± SD) L_∞ was 58.33 ± 1.79 cm TL and 58.78 ± 2.42 cm TL for Powell-Wetherall and FISAT methods respectively (Table 1). Luanda Gembe (62.50 cm) had the highest L_∞ and Homa Bay (56.60 cm) the lowest. The growth coefficient (*K*) had mean (± SD) of 0.59 ± 0.05 yr^{-1} with Homa Bay (0.68 yr^{-1}) and Kendu Bay (0.55 yr^{-1}) with the highest and the lowest respectively (Table 1). Values of *K* and L_∞ used for subsequent analysis. The growth performance index (ø) had mean (± SD) of 3.31± 0.04, with Luanda Gembe (3.36) achieving the highest and Dunga (3.26) the lowest (Table 1). The estimated total mortality coefficient (*Z*) had mean (± SD) 1.92 ± 0.64 yr^{-1}, natural mortality coefficient (*M*) at 1.00 ±0.06 yr^{-1}, fishing morality coefficient (*F*) at 1.12±0.34 and exploitation rate (*E*) at 0.52 ± 0.06 (Table 2). Mean (± SD) entry to the fishery at L_{25}, L_{50}, L_{75} was 20.96 ± 15.75, 26.18 ± 12.50, 28.54 ± 12.19 cm TL respectively (Table 3).

Discussion

Previous studies shows that L_∞ of *O. niloticus* has decreased from 64.6 cm TL in 1985/1986 to 56.7 cm TL 1998/2000, *K* increased from 0.25 yr-1 to 0.59 yr^{-1}, while ø has increased from 3.02 t0 3.27 at the same time (Table 4). The magnitude of ø is determined by *K* and L_∞, with and increase in *K* and reduction in L_∞ results in high ø. Diet type, exploitation, genetic make up may determine growth potential of a species (Ssentonga and Welcomme, 1985). The food types and their digestibility have been found to determine the difference growth patterns of Nile tilapia in natural waters. Bowen (1982) indicated that tilapia consumes food material of high calorific value, which are suitable for growth. In Lake Victoria, *O. niloticus* has shifted its feeding from herbivorous towards an insectivorous diet (Njiru 1999), and this could be contributing to high growth rate (*K*) and thus ø. Use of illegal fishing methods may lead to over exploitation and thus a reduction of the average size of fish caught and a faster growth rate. The fishing mortality (*F*) had a mean (±SD) of 1.25 ± 0.34, which is higher than previously reported in the lake. Over exploitation in Lake Victoria has also been documented by Ssentongo and Welcomme 1985; Othina and Tweddle 1999). Overexploitation results in reduction of average size of fish in a stock and a faster growth rate (Sparre and Venema 1998). The Kenyan portion of Lake Victoria constitutes only 6% of the entire lake, but it has the highest concentration of boats (8000) and fishers (30 000). The fishery is open access and there is no limit to the number of boats and gears used. The recommended gill mesh size for *O. niloticus* fishery of 5 inches, but 2-3 inches are commonly encountered. Destructive beach seines and trawling, although ban in the lake are still operational. At Homa Bay, with the highest *Z, F, K* and *E,* landings were by beach and mosquito seines.

Table 3 Nile tilapia probability of capture and sizes at which 25, 50 and 75% of the encountered fish were retained and optimum (L_{opt}) sizes, which would be realised in a location.

Station	L_{opt} (cm)	L_{25}(cm)	L_{50}(cm)	L_{75}(cm)
Dunga	35.80	38.21	40.19	36.16
Kendu Bay	32.35	35.74	38.30	36.81
Asembo Bay	28.74	31.45	31.31	38.35
Kendu Bay	32.35	35.74	38.30	36.81
Luanda Gembe	2.74	12.24	15.38	40.13
Mean±SD	20.96±15.75	26.18±12.50	28.54±12.19	37.64±1.61

Natural mortality has increased from 0.54 yr^{-1} in 1985/1986 to 1.00 yr^{-1} on 1998/2000 (Table). Faster growing fish have higher natural mortalities (Sparre and Venema 1998), and the warmer the ambient temperature the higher the natural mortality. Nile tilapia *K* has increased together with temperature (from 23 ^{0}C (Crul 1995) to 25 ^{0}C), and these could be contributing to the increased mortality.

The length at first capture (Lc_{50}) for *O. niloticus* with present commercial catch gears varied from 13.25 cm TL at Homa Bay to 38.21 cm TL at Dunga. In Kenyan waters of the lake, the smallest ripe *O. niloticus* male was 26.2 cm TL and female 23. 3 cm TL, fifty percent maturity for males was at 30 cm TL and females 33 cm TL (Ojuok 1999). Therefore, the present commercial gears in Kenyan waters of Lake Victoria are catching high proportions of immature *O. niloticus.* There has also been a reduction in the size at first maturity since the early 1990s when *O. niloticus* was maturing at an average length of 35 cm TL in Kenyan waters (Getabu 1992). This earlier maturation of tilapia could be a tactic to maximize reproductive success possibly linked to population response to over fishing.

Table 4. Growth parameters and growth performance of Oreochromis niloticus from Nyanza Gulf of Lake Victoria, Kenya.

L_∞(cm)	$K(yr^{-1})$	Φ	Z	M	F	E	Data collection	Source
64.60	0.25	3.03	0.82	0.54	0.28	0.34	1985-1986	Getabu (1992)
63.10	0.35	3.16	1.71	0.72	0.99	0.58	1989-1990	Dache (1994)
58.78	0.59	3.36	2.16	1.12	1.12	0.52	1998-2000	Present study

Continued use of mesh size smaller than recommended and the destruction of breeding grounds through the application of illegal fishing gears may lead to a further reduction of the size of *O. niloticus* at first capture. The fishers in turn will further reduce their mesh size and resort to illegal fishing methods to target the smaller fishes. This will result in a long-term decline of the size and catches of the species. However, even under these

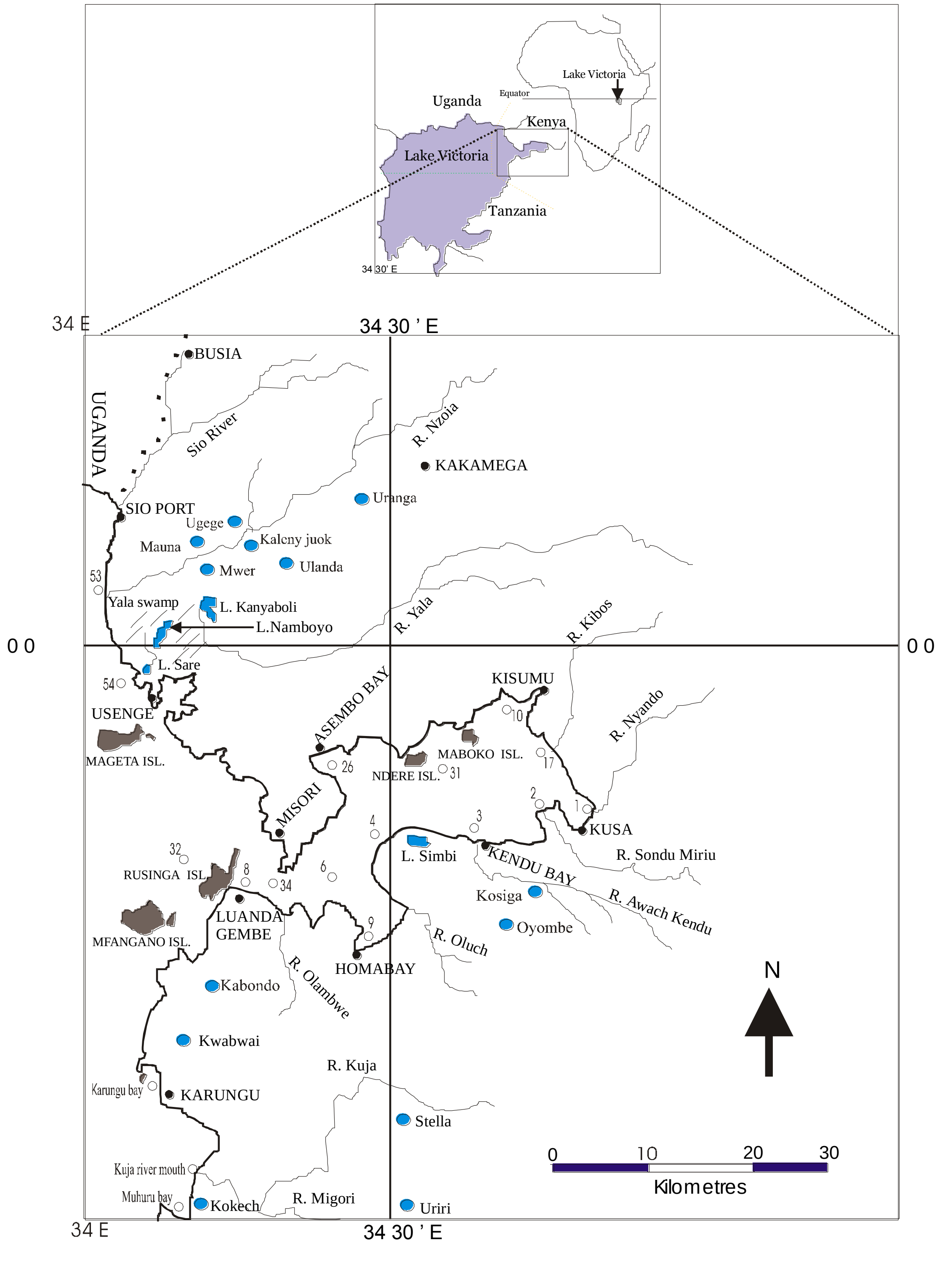

Fig. 1: Map of Nyanza Gulf, Lake Victoria showing sampling stations.

stressful conditions, *O. niloticus* shows a high growth performance index, attaining large sizes and if well managed, production could be increased. Higher production would provide more protein and income to people living around the lake and who depend so much on fishing because farming is not developed due to poor soils and unpredictable rains.

To sustain the fishery imposing the existing ban on beach seining, use of illegal mesh sizes and other destructive fishing methods need to the urgently addressed by the authorities concerned. The entry to the fishery, which is now open, should be limited and in addition to the registration of boats, licensing of nets should be introduced to help in monitoring the effort exerted on the fishery. Fishers should be provided with cold storage to avoid wastage and the landed fish should be sold through co-operative societies to improve returns. Law enforcers should increase their efforts and political interference in the running of the fishing industry should be reduced. Alternative sources of livelihood, such as aquaculture and farming, should be encouraged to reduce pressured on the fishery.

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Distribution, Status, and some aspects of the Biology of two Non-Cichlid Native Fishes of Lake Victoria, Kenya.

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Abstract

The status, distribution and some aspects of the breeding biology of mormyrids and *Brycinus* sp. was studied in the years 2000 and 2001 in the Kenyan portion of Lake Victoria. Five mormyrid species, *Mormyrus kanume* FORSK., *Pollimyrus nigricans* BLGR., *Marcusenius victoriae* WORTH. *Hippopotamyrus grahami* NORM., and *Gnathonemus longibarbis* HILG., and two species *of Brycinus, Brycinus Jacksonii* BLGR and *B. sadleri* BLGR. were recorded. *M. kannume* and *B. sadleri* occurred both at the river mouths and in the open waters while the rest of the species were restricted to certain river mouths only. The size distribution of these species in the lake consists of mainly larger ripe individuals. Of the mormyrids *P. nigricans* dominated with 62% while *M. kannume* accounted for <5% of the mormyrids caught.

The size range for each species caught, size at first maturity for both males and females and sex ratios are presented. The Possible reasons for the decline of the species numbers and abundance are suggested.

Key words: Distribution, Mormyridae, *Brycinus*, Breeding, Lake Victoria

Introduction

The native non-cichlid fish species of Lake Victoria once formed a basis for major fisheries. A drastic decline in the species like *Labeo victorianus*, *Alestes* (*Brycinus*) *sp*., Mormyridae and, *Barbus altianalis* was observed in the 1970s (Marten, 1979). Majority of these species are potamodromous and their decline has been attributed to intense fishing using small mesh gillnets and traditional traps at the river mouths, where ripe female and males congregate on their way to spawn in the riverine environment, leading to recruitment over fishing (Cadwalladr, 1965; Katunzi, 1985). Apart from over fishing, most of these species are threatened by modification of riverine regimes by human activities such as farming, settlement and pollution from factories, etc.

Although adoption of larger nets targeting *Lates niloticus* was reported to have led to an upward trend in the catches of traditional species (CIFA, 1982), most of these species have not shown any significant recovery (Pers obs.). It is thus imperative to examine the current distribution and abundance of the native non- cilchlids and to define the existing and potential threats to their survival. Their life history should also be obtained in order to develop recommendations for enhancing their status.

In this paper, the current status, distribution and some aspects of the breeding biology of the Mormyrids and *Brycinu*s of Lake Victoria, Kenya are described.

Materials and methods

Sampling was mainly done in the Nyanza Gulf and the Northern and Southern portions of the Kenyan waters of Lake Victoria (Fig. 1). Fish samples were obtained from small mesh gillnets (25.4 mm, 28.6 mm, 50.8 mm, 68.5 mm, 93.9 mm, 76.2 mm, 101.6 mm, 127.0 mm) set around the river mouths and the rocky areas. Additional samples were obtained through bottom trawls especially in the deep offshore areas. For each sampling site, the bottom and vegetation type were noted.

Fish were identified to species level and for each fish total length (TL, cm) was taken to the nearest cm, while total weight (g) was taken to the nearest gram. The fish were dissected, sexed and maturity status recorded.

Results

I. Mormyridae

(a) Distribution

Five species belonging to the family Mormyridae were recorded. Four small *mormyrid* species namely: *Pollimyrus nigricans*, *Hippopotamyrus grahami*, *Marcusenius victoriae* and *Gnathonemus longibarbis* were found associated with only two river mouths, Awach (Kendu bay) and Sio. The fifth species *Mormyrus kannume*, a large species hitherto of high commercial value, was recorded in the rocky areas around Asembo Bay, Mbita and at Nzoia river mouth. All the river mouths have soft bottom and have shallow waters with adjacent papyrus swamps. The small species were in nets set overnight. Nets set during the day had no mormyrids confirming remarks by Okedi (1969) that migration of the species was always at night, peak periods coinciding with dusk and dawn.

(b) Composition

The composition of the samples examined is summarised in Table 1.

Pollimyrus nigricans

Some biometric characteristics of *P. nigricans* are shown in Table 2. The size range of *P nigricans* examined was 6-11 cm TL. Male ranged from 6- 10 cm TL while female were in a higher length range (8-11 cm TL). Smallest ripe male was 7.5 cm TL weighing 5.5 g while smallest mature female was 8.0 cm TL weighing 6 g. This species accounted for 61.64 % of all the small mormyrid species.

Hippopotamyrus grahami

The size range recorded was 9-17 cm TL The smallest ripe male was 9.4 cm while the smallest ripe female was 10 cm (Table 2). It accounted for 23.3% of the small mormyrid species.

Figure 1. Map of Lake Victoria
showing study area

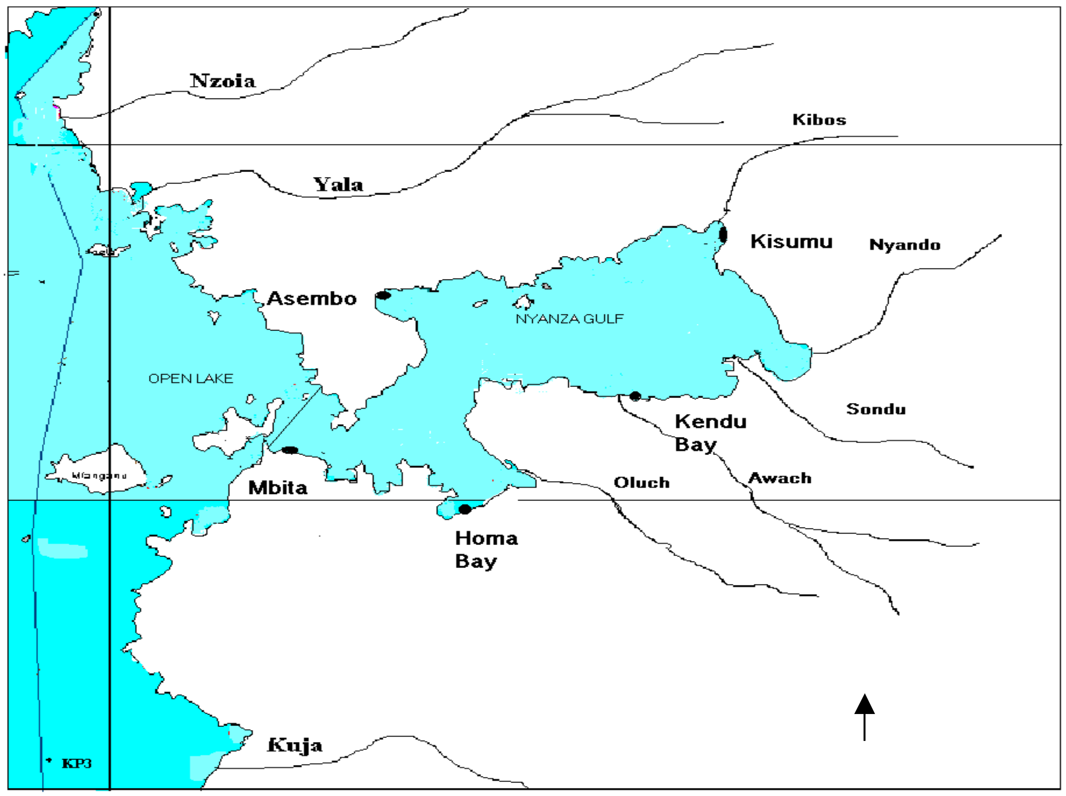

Figure 1: Map of Nyanza Gulf, Lake Victoria showing area of study.

Gnathonemus longibarbis

Size range of this species examined was 12-29 cm TL. The largest fish caught was a male while no female fish larger than 25 cm was caught. All the fish between 17-29 cm TL were ripe (Table 2). These results were consistent with observations made in Sio river (Okedi, 1969) However the lower length ranges appear to occur in the rivers which were not sampled in this study. *G. longibarbis* accounted for 8.22% of all the small mormyrids.

Marcusenius victoriae

The size range examine was 14-23 cm. At 15 cm both males and female were ripe (Table 2). This is in agreement with Observations of Greenwood (1966) that adult *Marcusenius* were usually between 15 and 20 cm long. However, it is strikingly different from Okedi (1969) who recorded a size range of 3.2-15.4 cm. This could be due to differences in the sampling sites. The percentage composition of this species was 6.9%.

Table 1. Species composition of four small mormyrid and *Brycinus species* in Lake Victoria, Kenya

Taxa	Occurrence
Mormyridae	
Pollimyrus nigricans	Awach (K/bay) & Sio river mouths
Hippopotamyrus grahami	,,
Marcusenius victoriae	,,
Gnathoonemus longibarbis	,,
Mormyrus kannume	Nzoia & Rocky areas (open Lake)
Characidae	
Brycinus sadleri	Awach, Oluch, Nyando, Sio & Mid Gulf
Brycinus jacksonii	Awach (Asembo)

Mormyrus kannume

Only a few samples were obtained and had a size range of 20-38 cm. Fish in the size range 31-38 cm were all mature.

(c) Sex ratio

The sex ratio of the smaller mormyrid species is shown in Table 3. Apart from *P. nigricans*, the rest of the small mormyrids did not differ significantly ($P < 0.05$) from the expected 1:1 ratio. In *P. nigricans* and *G. longibarbis* females dominated over males while in *H. grahami* males dominated.

Table 2. Some biometric characteristics of four small *mormyrid* and Brycinus species in Lake Victoria, Kenya

Species	No. Males	No. Females	No. Mature or ripe	Size range	Smallest ripe female (cm)	Smallest ripe male (cm)
P. nigricans	19	55	66	6.0-11.0	8.0	7.5
H. grahami	7	3	10	9.0-17.0	10.0	9.4
G. longibarbis	7	5	12	12.0-29.0	17.0	17.0
M. victoriae	4	7	11	14.0-23.0	15.0	15.0
B. sadleri	64	83	130	4.0-12.0	7.0	5.0
B. jacksonii	129	55	176	12.0-22.0	16.0	12.5

(d) Length Frequency distribution

The length frequency distribution of four mormyrid species is shown in Figures 2-5. The histograms indicate that the component in the population to which majority of fish in the lake belongs consists of large individuals that are mainly ripe.

II *Brycinus* sp. (Pisces: Characidae)

Two species, *Brycinus jacksonii* and *B. sadleri* were recorded.

(a) Distribution

B. jacksonii
This species occurred in very few numbers in the main lake and the river mouths within the Gulf. However it was found unique to Awach river mouth near Asembo Bay where it occurred in very high numbers (> 90 % of all the samples obtained).

Table 3. *Sex ratio of the mormyrid &* Brycinus *species examined in L. Victoria, Kenya*

Species	No. Males	No. Females	M : F	χ^2
P. nigricans	19	55	1: 2.89	68.21*
H. grahami	7	3	1: 0.43	2.28
M. victoriae	7	5	1: 0.71	0.57
G. longibarbis	4	7	1: 1.75	2.25
B. sadleri	64	83	1: 1.30	5.64
B. jacksonii	129	55	1: 0.43	42.45*

* Significant at *P*> 0.05

B. sadleri
This occurred in abundance at the river mouths and in the pelagic zone associated with *Rastrineobola argentea*. Highest occurrence was associated with Awach river mouth in Kendu Bay, Awach (Asembo Bay), Nyando, Oluch and Sio river mouths. Few samples were found in the mid-Gulf, far away from the river mouths.

(b) Composition
The composition of the characids examined is summarised in Table 1.

B. sadleri
The size range recorded was 4-12 cm TL. This is in agreement with what was reported by Getabu (1988). The smallest ripe female was 7.0 cm while the smallest ripe male was 5 cm (Table 2).

B. jacksonii

The size range recorded was 12-22 cm TL. The smallest ripe female was 15.5 cm and the smallest ripe male was 12.5 cm (Table 2).

(c) Sex ratio
The sex ratio for the two *Brycinus* species is shown in Table 3. In *B. sadleri* there were more females than males while in *B. jacksonii* males were more than females and the ratio was significantly different from the expected 1:1 ratio ($\chi^2 = 68.21$; $P > 0.05$).

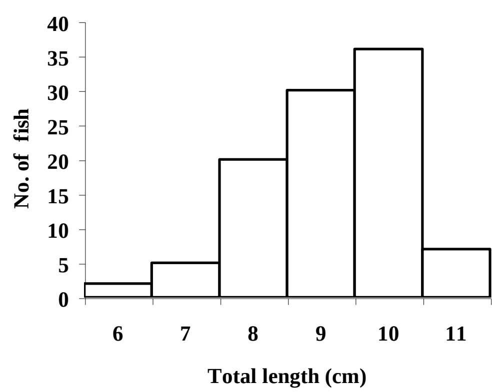

Fig. 2: Length frequency distribution of *P. nigricans* in Lake Victoria, Kenya

(d) Length- frequency distribution
Analysis of the length frequency histograms for *B. sadleri* (Fig. 6) and *B. jacksonii* (Fig. 7) show two components in the population. The component to which majority of fish belong consists of larger individuals. The smaller individuals/ juveniles are very few and probably occur in the riverine environments.

Discussion
Seven mormyrid species have been reported in Lake Victoria (Greenwood, 1966; Okedi, 1969). Okedi (1969) reported five small mormyrids, *Gnathonemus longibarbis, Marcusenius victoriae, Pollimyrus nigricans, Hippopotamyrus grahami and Petrocephalus catostoma* in the Lake Victoria basin especially, in the Sio river in western Kenya. In this study, only four of the smaller mormyrids and one larger species,

Mormyrus kannume, were recorded. *Petrocephalus catostoma* was not recorded at all in the four months of sampling. This species could be confined to the rivers and these were not sampled in this study. Although there is no directed fishery for mormyridae, the number caught in this study was quite low despite intensive gillnetting, with *Pollimyrus nigricans* forming the bulk of the catch (62%).

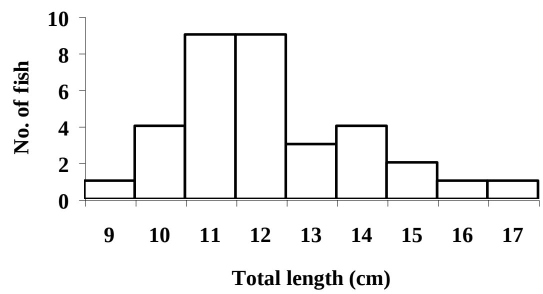

Fig. 3: Length frequency distribution of *Hippopotamyrus grahami* in Lake Victoria, Kenya

The absence of the juveniles of the small mormyrid species in lake may indicate that these species feed in lakes and rivers and spawn in rivers only. Indeed, the high occurrence of the ripe fish caught at the river mouths was a pointer of fish moving into the rivers to spawn. However, for *M. kannume* the occurrence of ripe fish both at the river mouths and in areas very far away from the influence of these rivers such as the rocky and sandy areas around Mbita could mean that spawning takes place both in the lake and rivers. It could also be possible that the currents and turbulence in the rocky areas around Mbita channel offer conditions resembling those in the rivers thus triggering spawning.

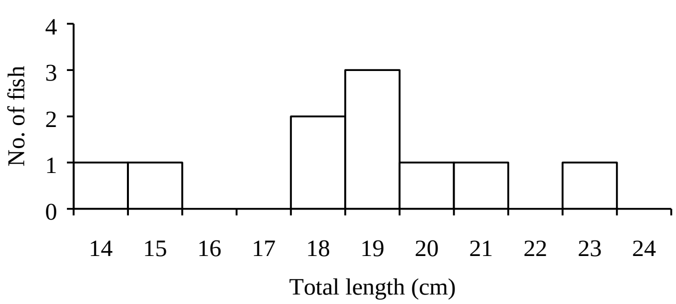

Fig. 4**:** Length frequency distribution for *Marcusenius victoriae* in Lake Victoria, Kenya

The sex ratios calculated for *P. nigricans*, departed significantly from the expected 1:1 and this could have been due to the differential migration of the sexes during their breeding cycle.

Brycinus jacksonii was uniquely associated with particular river mouths and it would be important to know the factors controlling such distribution pattern. Males matured at smaller size in the two *Brycinus* species. Over 90% all the fish caught both in dry and wet months were ripe, implying that breeding could be continuous and not necessarily synchronised to the rainy seasons. Whereas *B. sadleri* occurred in the pelagic areas far from the river mouths, *B. jacksonii* were confined to the river mouths only.

Conclusion

Although the two families investigated are not targeted for fishery, their abundance seems to have considerably declined. Some possible reasons for this decline could be the interference with the breeding grounds through human encroachment of the wetlands, industrial and domestic pollution of certain river systems. These could be supported by the fact that most of the species were associated with certain rivers only. Investigations into the water quality of the inflowing rivers may be very vital to the understanding of the distribution and abundance of these species.

Acknowledgements

I would like to thank the Director, Kenya Marine and Fisheries Research Institute (KMFRI) for providing facilities for this study. Lake Victoria Management Programme (LVEMP) and Lake Victoria Fisheries Research Project (LVFRP) funded this study. I would also like to thank KMFRI staff that participated in the data collection.

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The role of reproductive strategies in recovery and success of selected fish species of Lake Victoria,Tanzania.

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Abstract

Breeding success differs among fish species and within species depending on various aspects including selection of mates, parental care, environmental conditions, clutch size, gonadal maturation and genetic differences in fitness. The present study which started in 1997 investigated factors which favour the reproduction of three fish species, *Lates niloticus, Oreochromis niloticus* and *Schilbe intermedius*. The factors investigated included parental care, clutch size, resource mobilization from the environment and gonadal maturation. The results show that *Oreochromis niloticus* spawns a few eggs about 3,550 in relation to its size (about 57cm in total length). Its success is ensured by being a mouth breeder which is the highest parental care. The other fish species *L. niloticus* and *S. intermedius* have no parental care to the laid eggs but spawn large number of eggs in relation to their sizes. Regarding the gonadal maturation the results show that *L. niloticus* and *S. intermedius* males have shown to attain sexual maturity much earlier than females. This is a strategy to have many mature males to fertilize the eggs of any female which attains sexual maturity.

Key words: Reproduction, Strategies, Brooding, Clutch, Maturity

Introduction

Differences in the reproductive strategies of different sexes may ultimately be consequences of the relative gamete sizes of females and males (Williams, 1975; Dawkins, 1976). Reproduction is a complex process both to the parent stock and the offspring. It is assumed that reproduction is associated with the subsequent survival of the parent and its future reproductive performance (Calow, 1979). Normally there is an inverse relationship between clutch size and egg size, that is for a given reproductive output, a female could produce a few large eggs or many small ones. However, individuals with large amounts of reproductive resources may produce both larger eggs and larger clutches than those with a smaller total reproductive output.

Determining the strategies of reproduction of a species is important because it forms an integral part of the description of its biology. This is the case because the number and timing of spawning during a year may affect their recruitment and consequently many interactions. The present decline of biodiversity in Lake Victoria have been attributed to various reasons apart from environmental changes and overfishing. The success or decline of species in Lake Victoria could be associated with differences in reproductive tacts.

The Present study investigated the role played by different reproductive strategies which lead to the success of *Lates niloticus* and recovery of *Schilbe intermedius* and *Oreochromis niloticus* in Lake Victoria, Tanzania.

Materials and methods

Sample Collection

Samples of *L. niloticus* and *Schilbe intermedius* were obtained from Speke gulf while those of *Oreochromis niloticus* were obtained from EminPasha gulf (Fig. 1). Samples were collected using a stern trawler R.V. TAFIRI II with 150 HP operating a trawl net of 30mm cod end. Sampling concentrated in inshore waters of depths ranging between 3 and 20 metres. Each trawl operation took 30 minutes, on retrieval of the net the target fish species were randomly picked including all size ranges for examination of parental care, clutch size, gonadal maturation and food items taken. A total of 50 individuals for each species were examined. Sampling was carried out in March, July and December 2000.

Data Collection

After taking individual length and weight the following parameters were examined; Maturity status according to Hopson (1972) for *L. niloticus* and modified from Hopson (1972) for *Oreochromis niloticus* and *Schilbe intermedius*. The maturity status gave the size at first maturity. The variety of food items taken was also investigated. Another aspect investigated was the clutch size (fecundity). Ripe ovaries were collected and preserved in 10% formaldehyde. In the laboratory a pair of ovaries were weighed to get the total weight. Then sub sample weights of 0.01g for *L. niloticus* and 0.1g for *O. niloticus* and *S. intermedius.* Were taken in triplicates from which the sample number was obtained. The total number of eggs was calculated from which the sample number was obtained. The total number of eggs was calculated from the following equation:

$$F = \frac{OW}{SW} \times SN \quad \ldots\ldots (1)$$

Where: F = fecundity
OW = total ovary weight
SW = ovary sample weight
SN = the number of eggs from the sample.

The parental care of the fish species was obtained from the available literature.

Results

Parental care and Clutch size

Two types of parental care exist, namely *Oreochromis niloticus* is a mouth brooder while *L. niloticus* and *S. intermedius* spawn in open waters. Regarding the clutch size the results show that *Lates niloticus* ranging from 81.0 to 153.0 cm produced eggs ranging from 800,000 to 17,336,000 with a mean diameter of about 0.51 $\pm$ 0.1mm. *Oreochromis niloticus* of about 26.8 – 56.0 cm had eggs ranging between 1,240 and 6,600 with a diameter of about 2.2 $\pm$ 0.39mm. *Schilbe intermedius* of about 11.0 – 34.0 cm produced eggs ranging between 2,770 and 10,500 with a mean diameter of 1.0 $\pm$ 0.1mm.

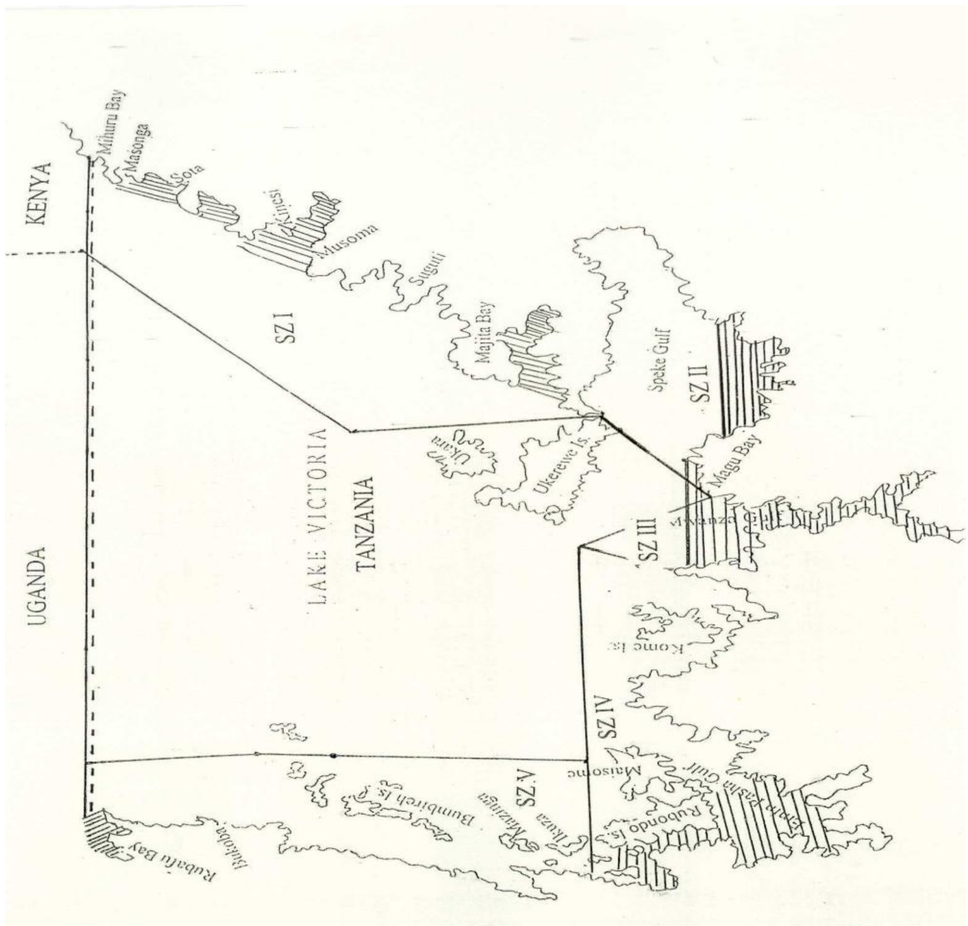

Fig. 1.1: Map of Lake Victoria (Tanzania) showing the study area.

3.1 Environmental factors

The foraging ability on various food resources is the most important environmental factor influencing reproductive ability. Table 1 shows the different food items taken by the fish species. It can be seen that, *Lates niloticus* is exclusively carnivorous feeding on a variety of food items including *Caridina nilotica*, *Haplochromis* species, *Rastrineobola argentea*, insect larvae, fish species, gastropods and worms. Cannibalism was also evident in *L. niloticus*. *Schilbe intermedius* fed on *Haplochromis* species, *Caridina nilotica*, fish and other invertebrates. *Oreochromis niloticus* fed on phytoplankton, detritus materials and *Caridina nilotica.*

Table 1: Food items consumed by different fish species from Lake Victoria, Tanzania

	FISH SPECIES		
Food items	L. niloticus	S. intermedius	O. niloticus

Caridina	X	X	X
Haplochromis spp.	X	X	
R. argentea	X		
Fish remains	X	X	
Insect larvae	X	X	
Gastropod	X		
Worms	X		
Phytoplankton			X
Detritus			X
Cannibalism	X		

X = Food item present

Size at First Maturity

The size at first maturity of *Shilbe intermedius* is presented in Fig. 2. The results show that males reached sexual maturity at a smaller size (18.0 cm) than females (22.0 cm). Male *L. niloticus* also reached sexual maturity at a smaller size (67.0 cm) than females (95.0 cm) as presented in Fig. 3.

Discussion

Parental Care and Clutch Size

The parental care was higher in *Oreochromis niloticus* as a mouth brooder which increases the chances of hatching the eggs. The number of eggs produced could depend on the size of the individual, size of the eggs and nature of the parental care. The big clutch size of *L. niloticus* and *S. intermedius* with small eggs (0.51mm and 1.0 mm in diameter respectively) is an adaptation to the hash environment to which the eggs are exposed to without any parental care (Bayne *et al.*, 1983). Under such environment the eggs suffer from predation, fungal infection and suffocation in stagnant water (Avyle, van Den, 1984). *Oreochromis niloticus* produces a small number of eggs which are large with an average diameter of 2.2mm because there is a high parental care. Generally brood size decreases with an increase in offspring survival (Morris, 1987).

Environmental Factors

The results show that *L niloticus* has high range of foraging ability taking many food items and occupying different niches. Basically *Lates niloticus* is a bottom dwelling species but it has been reported that it also stays and forages in the pelagic environment. This phenomenon is probably related to the fact that the fish has a relatively high demand for oxygen (Fish, 1956). As such *Lates niloticus* has enough or surplus energy source for reproduction, this is quite common in long lived species (Ware, 1984).

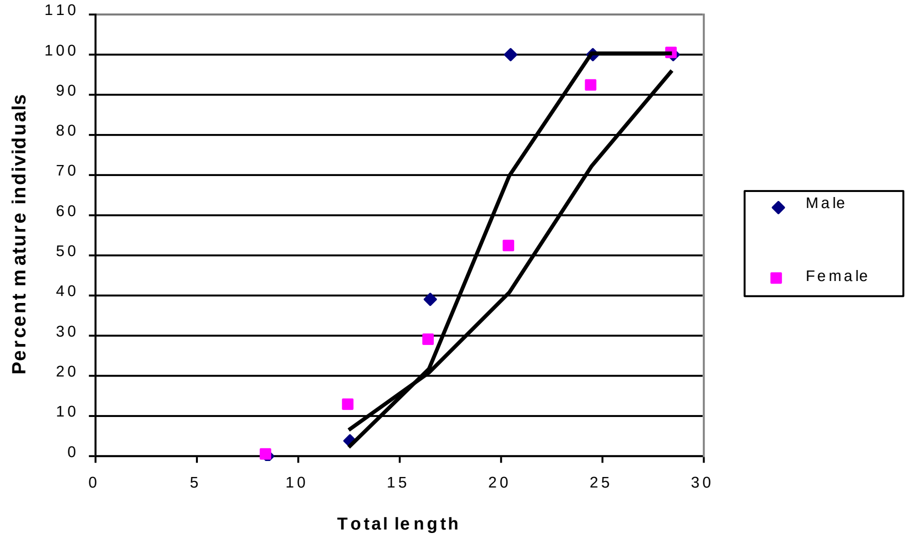

Figure 2: Size at first maturity of *Schilbe intermedius* of Tanzania waters from Lake Victoria during 2000.

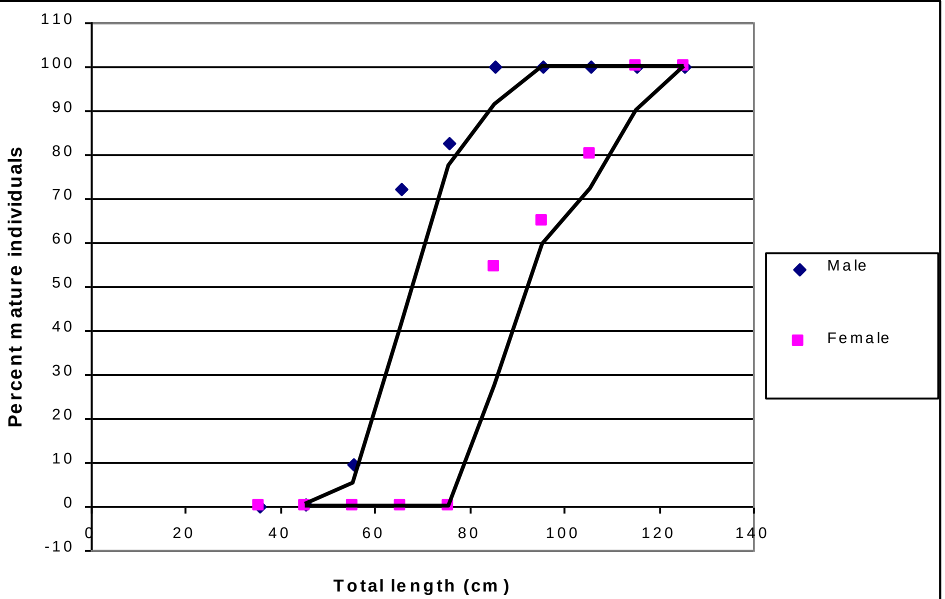

Figure 3: Size at first maturity of *L. niloticus* of Tanzania waters from Lake Victoria

The fact that the fish practices cannibalism also becomes a reproductive strategy. Cannibalism minimizes time spent foraging and maximizes time spent on activities that increase the probability of initiating and successfully completing one or more reproductive cycles (Hyatt and Ringler, 1989). Although the benefits of cannibalism are most obvious for populations breeding under conditions where food supplies limit their potential reproductive output, the benefits may still apply even under conditions where alternative prey sources appear to be abundant (Hyatt and Ringler, 1989). The importance of food sources in reproduction lies on gamete production (MacDonald and Thompson, 1985). Normally brood size increases with an increase in energy investment (Morris, 1987).

The recovery of *S. intermedius* in the environment could also be a result of its ability to forage on a variety of food items. Probably this has enabled it avoid from being preyed upon by *L niloticus* by occupying different ecological niches at times.

Size at First Maturity

The results show that male *L. niloticus* and *S. intermedius* reached gonadal maturity at a smaller size than females. This could be a reproductive strategy, to have many mature males to fertilize the eggs of any female which attains sexual maturity. Males determine the breeding success and normally they are very variable (Howard, 1979).

Conclussion and recommendation

Food source for the fish species are found to be very important in improving the reproductive output. Since *L. niloticus* and *S. intermedius* forage on many fish species including juveniles it is recommended that a closure system of the habitats and time be imposed in the bays to reduce fishing pressure. This would in turn provide enough prey items to the predators.

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Fish species composition, distribution and abundance in Lake Victoria basin, Kenya.

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Abstract

Fish species composition, distribution and abundance in Lake Victoria, Kenya and the surrounding dams and satellite lakes were studied from 1997 to 2001 The study revealed that lake Victoria had a total of 37 species representing ten families. *Lates niloticus* dominated the catches in terms of ichthyomass in Lake Victoria while haplochromine cichlids are still the richest in species diversity followed by *Barbus.* The haplochromines however showed an upward trend in biomass compared to 1980s.

In the satellite lakes, a total of 28 species belonging to ten families were recorded. Haplochromine cichlids were the most diverse group followed by *Barbus*. The endemic, *Oreochromis esculentus* was the dominant species among the tilapiines especially in Lake Kanyaboli. Lake Sare had the highest species richness and diversity.

In the dams *Clarias gariepinus* and *Oreochromis nilotica* was the most widely distributed species while *Barbus* had the richest species diversity. The endemic tilapiines, *Oreochromis esculentus* and *O. variabilis* were also recorded in the dams. The fish species assemblage in the dams and the satellite lakes demonstrates the importance of these water bodies in fish biodiversity conservation.

Key words*:* Lake Victoria, satellite lakes, dams, species composition, and distribution

Introduction

Lake Victoria was the home of unique and diverse fish fauna such as *Haplochromines, Labeo victoriarus* Boulenger, *Brycinus* spp, *Barbus* spp, *Momyrus* spp and *Synodontis spp* (Graham, 1929; Greenwood, 1966 and Ogari, 1984) that formed a special delicacy to the lakeshore communities. This diversity of Lake Victoria Harplochromines provided areas of scientific interest to biologist and taxonomists worldwide.

In the recent past, the human population around the lake basin has increased tremendously which in turn has increased socio-economic demands such as agricultural land, industrialization and urbanization. The effect of all this has been intense pressure through sediment pollution from poor agricultural practices, urban and industrial effluents resulting into serious environmental degradation of Lake Victoria.

In the period 1950–1962 non- endemic fish species such as *Oreochromis niloticus* (L.), *O. leucostictus* (Trewavas), *T. Zillii* (Gervais) *and Lates niloticus* (Linnaeus) were introduced into Lake Victoria (Ogari, 1984). Factors such as introduction of alien fish species, (Mwalo O. M. 1991, Welcomme, 1966, Fryer1973) increase in population, the use of wrong fishing gears and methods, (Ogutu-Ohwayo *et, al.1991*) destruction of the breeding and nursery grounds for the endemic fish species coupled with changes in environmental conditions (Ochumba *et, al* 1991) resulted in considerable changes in fish faunal composition. Today most of the endemic fish species are rarely encountered in Lake Victoria (Witte *et al*., 1992) and some are threatened with extinction in the Lake. (Ochumba *et, al* 1991, Witte *et al*., 1992). The endemic fish species that have now disappeared from Lake Victoria could now be found in the satellite lakes, dams and associated wetlands within the Lake basin .One main characteristic of these water bodies is the absence of *Lates niloticus* and most of these water bodies are heavily colonized by dense masses of emergent and sub-mergent aquatic macrophytes which form significant barriers to the dispersal of fish species intolerant to low oxygen and high turbidity levels such as *Lates niloticus* (Fish, 1956).

In view of reduced diversity and the threat of extinction of some native and exotic fish species from Lake Victoria, a need therefore, arose to ascertain and locate these threatened species in other water bodies in the Lake basin. This effort is directed at conserving this lost biodiversity of Lake Victoria in other water bodies and establishing the diversity and sanctuary sites where these species are still thought to be flourishing. This was the main objective of this study

Study area

Fig.1 shows the area in which this study was undertaken. Lake Victoria is the second largest fresh water lake in the world measuring 68,800 km^2. With a shoreline of 3,450m2, mean depth of 40m and maximum depth ranging from 70 to 90 m, it is shared between Kenya 6%, Uganda 43% and Tanzania 51%. It derives its water directly from rainfall which accounts for 90% of the total water into the Lake (Talling, 1966) .The Kenyan part of the lake is fed by several rivers including, Nyando, Sondu-Miriu, Awach, Nyando on the East and Southern side and Nzoia, Yala, Sio on the North and Western parts of the lake. The satellite lakes studied were Lakes Kanyaboli, Sare and Namboyo within the vicinity of Yala swamp in the northern part of Lake Victoria. Besides Lake Sare which discharges it waters directly into Lake Victoria the other two lakes discharges their water through underground seepage. The saline Lake Simbi in the southern part of Lake. Victoria lies at a distance of about 1 km from the shores of Nyanza Gulf. Further description of this lake can be found in Melack (1976, 1979). The dams are heavily colonized by dense masses of emergent and sub-mergent macrophytes (*Ceratophyllum, Cyperus papyrus, C. latifolia, C. immensus, Typha domingesis, Potamogeton schweinfurthii, Vossia cuspidate, Najas horrida* and *Nymphae spp.* A total of 15 dams were investigated

Materials and methods

Fish samples were collected using a bottom trawl net in all established stations in the Lake Victoria. At the river mouths multifilament nets of varying mesh sizes (1'', $1^1/_4$'', $1^1/_2$'', 2'', $2^1/_2$'', 3'', $3^1/_2$'',4'', $4^1/_2$'') were set overnight. In the satellite lakes and dams, varying mesh sizes of multifilament gillnet were cast in the open waters free from macrophytes colonization whereas in shallow areas and areas colonized by emergent and submerged aquatic macrophytes minnow traps were set overnight. Fish samples were sorted out according to families and species where possible. The total and individual weight of each species were taken to the nearest 0.1 g while total length for each specimen was measured to the nearest 0.1cm

In the lab and field identification was done using external morphological characteristics and identification keys by (Greenwood 1966; Boulenger 1915, 1916; Trewavas 1983 and Witte & Densen 1995).

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Results

Lake Victoria

(a) Fish species distribution and composition

A total of 37 species were recorded out of the 21 sampled stations, representing eleven families (Cichlidae, Mochokidae, Schilbeidae, Clariidae Protopteridae, Cyprinidae, Characidae Centropomidae, Mormyridae Bagridae and Mastercembalidae) (Table 1). *Oreochromis niloticus, Yssichromis laparogramma* and *Y. fusiformis* were the most widely distributed cichlids species occurring in almost all the sampled stations. *Oreochromis leucostictus, Tilapia zilli* Gervais and *Tilapia rendalli*, *Astatotilapia SP Ptychromis sp*, *Paralabidochromis sp* were rare and occurred in only three stations. *Synodontis victoriae* Boulenger and *Synodontis afrofischeri* Hilgendorf belonging to the family Machokidae occurred in three stations and at the river mouths. *Schilbe intermedius* (Linnaeus), *Clarias gariepinus* Burchell,

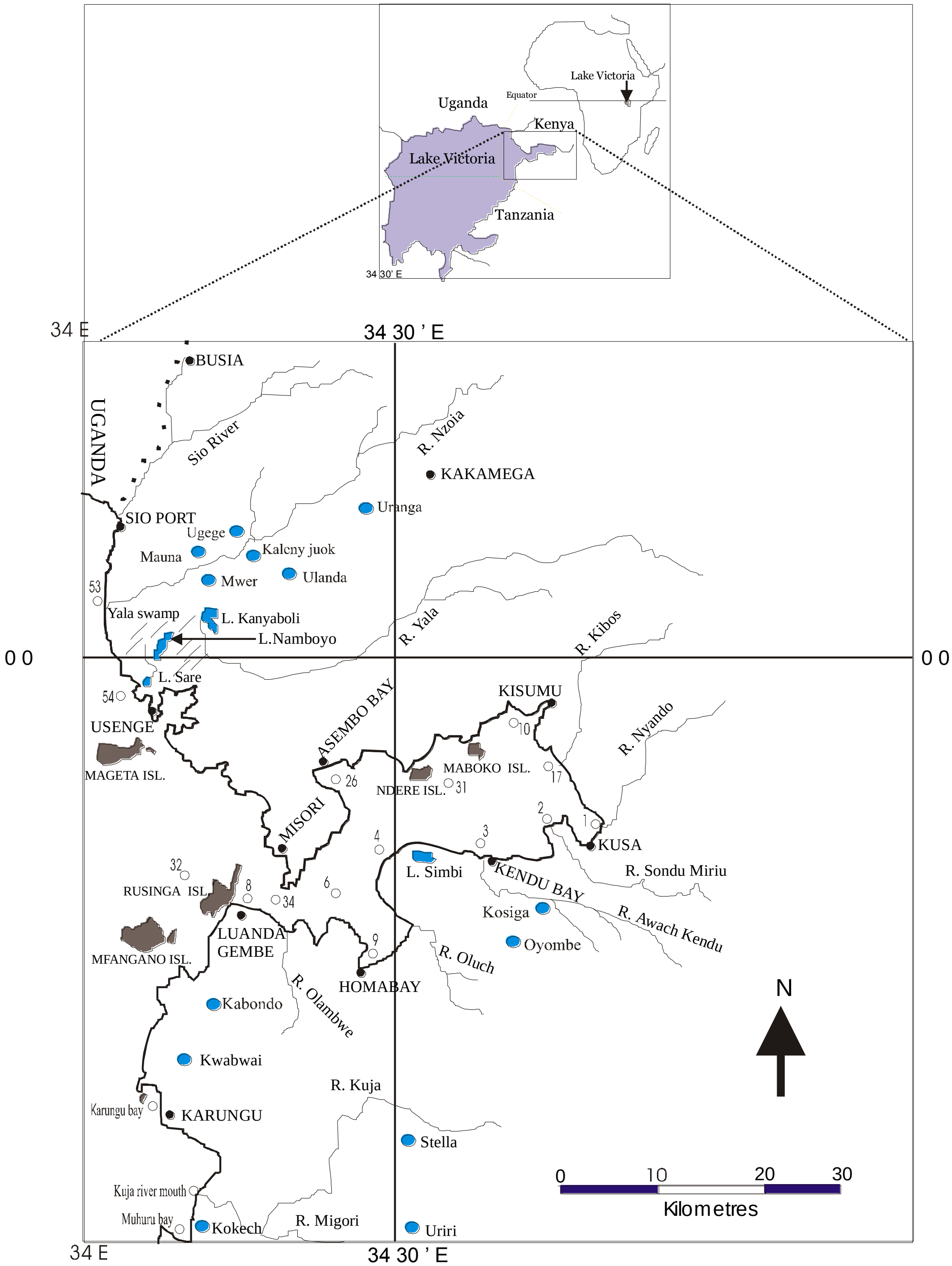

Figure 1: Map of Lake Victoria showing the sampled stations in the main lake, satellite lakes and dams

Protopterus aethiopicus Heckel occurred in most of the stations while *Bagrus docmac*, and the fresh water eel *Mastercembelus frenatus* were each recorded in only one station.

Rastrineobola argentea (Pellegrin) was the abundant cyprinid with a 100% occurrence at all the stations. *Barbus profundus, B. kersteni, B. jacksonii (*Gunthe*r), B. altianalis, B. apleurogramma* Boulenger *and B. trispilopleura* were each recorded in only two stations. Family Characidae was represented by *Brycinus sadleri* and *Brycinus jacksonii* with the latter accounting for 52.9% in all the stations. *Lates niloticus* was widely distributed and occurred in all the stations.

(b) Fish species abundance

Fish species abundance in (Fig. 2) terms of icthyomass was dominated by ***Lates niloticus*** constituting 60% followed by ***Oreochromis niloticus*** at 25%, ***Harplochromines*** 15%, ***Clarias gariepinus*** 5% and ***Protopterus aethiopicus*** at 2,5%. *Rastrineobola argentea* constituted less than 2.5% in these results due to the gear that was used and his does not mean that its biomass is low. Others constituted *Oreochromis leucostictus* (Trewavas), *Tilapia rendallii, Synodontis victoriae, Synodontis afrofischeri, Schilbe intermedius,* and *Brycinus sadleri* each contributed less than 1% of the total biomass in the sampled stations.

Satellite lakes

Fish species distribution and composition

The composition and distribution in the satellite lakes in the Lake Victoria basin is shown in Table 2. A total of 28 species belonging to some ten families were recorded. The Haplochromine cichlids were not identified fully but they still lead in species number and biodiversity. Fishes of the genera *Barbus* were the second in terms of biodiversity. The species were not however, equally distributed in the satellite lakes, Lake Sare had the highest number and diversity for *Barbus* species while Lake Kanyaboli had the highest diversity for the haplochromines. All the three lakes (Table 2) were found to harbor *Oreochromis esculentus*, a native cichlid that is now thought to be commercially extinct in Lake Victoria. The native non-cichlids like the mormyrids, *Clarias alluaudi*, *Protopterus aethiopicus* and *Ctenopoma murei* were also recorded in the satellite lakes. In terms of species richness and biodiversity, Lake Sare is leading followed by Lake Kanyaboli and then Namboyo.

Dams

Fish species distribution and composition

The fish species composition and distribution in 15 dams within Lake Victoria basin is shown in Table 3. Some 25 species belonging to five families were recorded. The families found include Cyprinidae, Cichlidae, Clariidae, Mastacembalidae and Protopteridae. Cyprinidae dominated in the total number of species within a family. *Clarias gariepinus*, *Oreochromis niloticus* and *Barbus* a*pleurogramm* were the most widely distributed, occurring in all the dams. The endemic tilapiines, *Oreochromis esculentus* and *O. variabilis* were found mainly in the dams to the north of Lake Victoria.

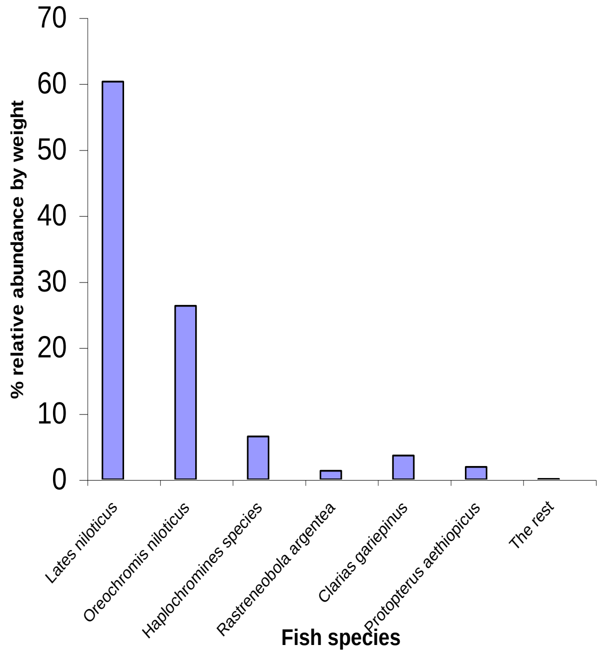

Fig. 2. Relative abundance of fish species in the sampled stations of Lake Victoria

Table 1.Fish species distribution in the sampled stations of Lake Victoria, Kenya

	SAMPLING STATIONS																					
TAXA	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**9**	**17**	**17A**	**26**	**30**	**31**	**36**	**36A**	**37**	**M. Mbili**	**Kuja**	**50**	**53**	**54**	**% Occ**
Cichlidae																						
Oreochromis niloticus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	100
O. leucostictus			X						X													5.8
Tilapia zillii		X	X																	X	X	11.6
Tilapia rendalli								X												X		5.8
Xystichromis sp.							X	X	X				X					x				17.6
Yssichromis laparogramma			X	X	X	X	X	X	X		X	X	X	X		X	X	X				76.4
Y. uniforms						X	X	X	X			X		X		X	X	X				58.8
Astatostilapia sp.			X															X				5.8
Paralabidochromis kribensis			X				X															5.8
P. chilotes				X			X								X			X				11.6
P. plagiodon				X			X								X			X				11.6
Paralabidochromis sp.							X											X				5.8
Ptychromis sp.						X	X											X				11.6
Other Haplochromines		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	100
Mochokidae																						
Synodontis afrofischeri			X											X				X		X	X	17.6
S.victoriae			X	X												X				X	X	17.6
Schilbeidae																						
Schilbe intermedius			X	X											X	X				X	X	23.5
Clariidae																						
Clarias gariepinus			X		X			X		X	X	X		X	X	X	X					52.9
Propteridae																						
Protopterus aethiopicus							X	X		X		X	X									17.6
Cyprinidae																						
Rastrineobola argentea	X	X			X	X	X	X	X	x	X	X	X	X	X	X	X	X	X	X	X	100
Barbus profundus		X																		X		5.8
Barbus kersteni		X																		X		5.8
Barbus trispilopleura			X					X														5.8
Barbus jacksonii			X					X														5.8
Barbu altianalis					X			X														5.8
Barbus neumayeri					X											X						5.8

Barbus apleurogramma					**X**																	**5.8**
																				X		
Barbus cercops			**X**	**X**	**X**		**X**													**X**		**11.6**
Characidae																						
Brycinus sadleri	**X**	**X**		**X**	**X**			**X**			**X**	**X**	**X**			**X**						**52.9**
B. jacksonii	**X**	**X**									**X**	**X**										**11.7**
Centropomidae																						
Lates niloticus	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**100**
Mormyridae																						
Mormyrus kannume			**X**																			**5.8**
																				X		
Gnathonemus longibarbis			**X**																	**X**		**5.8**
Marcusenius victoriae			**X**																	**X**		**5.8**
Bagridae																						**5.8**
Bagrus docmac						**X**																**2.6**
mastercembalidae																						
																	X					**2,6**
Mastercembelus frenatus																						

Discussion

The decline of the native fish species in Lake Victoria has been attributed to predation by the introduced Nile perch, use of wrong and destructive fishing gears especially around the river mouths and to some extent destruction of spawning and nursery grounds through human encroachment (Ogutu-Ohwayo *et, al.1991* Ochumba et, al.1991). Until the end of 1970s more than 80% of the demersal fish biomass of Lake Victoria consisted of haplochromine cichlids (Kudhongania & Cordone, 1974). Since the upsurge of *Lates niloticus* in the 1980s, the haplochromine stock and its fishery declined in the major parts of the Lake Victoria, particularly in the sub-littoral (6-20 m) and deepwater (>20 m) (Witte *et al*., 1992). Besides haplochromine cichlids, about 10 other genera, belonging to several families, contributed to the fisheries. Since the beginning of the century, the two indigenous tilapiine cichlids, *Oreochromis esculentus* and *O. variabilis* had been the most important target species (Fryer & Iles, 1972; Lowe-McConnell, 1987). These two species no longer occur in the lake in appreciable quantities. In addition to these cichlids, some native non-cichlid species of the family Mormyridae, Cyprinidae and Clariidae are threatened with extinction

Results from this study have revealed that these species now extinct or threatened in Lake Victoria, occur in substantial numbers in the satellite lakes and dams within the Lake Victoria basin. Further the results revealed that the haplochromines now occur in almost all parts of the lake and have increased in biomass. The second species rich in diversity after the haplochromines is *Barbus* with 8 species recorded in the lake and in the dams within L. Victoria basin. They were however more abundant in the dams than the main lake.

The introduced, *Oreochromis niloticus* is the dominant among the tilapiines in the main lake. *Tilapia rendalli* and *T. zillii* no longer occur in great quantities in both the main lake and the dams. The native non-cichlids rarely encountered in the lake and in the dams currently include *Bagrus docmac*, *Mormyrus kannume*, and *Mastercembelus frenatus. Lates nioloticus* still remains the most dominant species, followed by *Rastrineobola argentea* and *O. niloticus.*

Conclusion

These findings point to the importance of the satellite lakes and dams in the conservation of biodiversity. Lake Sare for example had the highest biodiversity among all the satellite lakes. During this study however it was noticed that in both Lake Kanyaboli and Sare, destructive fishing methods are in operation and these may cause further loss in biodiversity. Proper management guidelines such as mesh sizes, closed fishing seasons and banning of fishing in the breeding grounds must therefore be enforced to regulate and control the fishing activities in these water bodies.

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Table. 2 Fish species composition in satellite lakes of Lake Victoria basin, Kenya.

	LAKES			
TAXA	**KANYABOLI**	**SARE**	**NAMBOYO**	**SIMBI**
Anabatidae				
Ctenopoma murei	X	X		
Cyprinidae				
Barbus apleurogramma	X	X	X	-
Barbus paludinosus	X	X		-
Barbus karstenii	X	X		-
Barbus neumayeri		X		-
		X		-
Barbus altinalis				
				-
Cichlidae				
	X	X	X	-
Oreochromis niloticus				
Oreochromis esculentus	X	X	X	-
Oreochromis variabilis				-
		X		-
Oreochromis leucostictus				
Haplochromine spp.	X	X	X	-
Astatoreochromis alluaudi	X	X		-
Astatotilapia nubilus	X			-
Xystichromis phytophagous	X			-
Xystichromis sp.	X			-
Lipochromis maxillaris	X			-
Pseudocrenilabrus multicolor	X			-
Clariidae				-
	X	X		-
Clarias gariepinus				
Clarias alluadi	X	X		-
Protopteridae				-
	X	X		-
Protopterus aethiopicus				
Centropomidae				-
		X		-
Lates niloticus				
Mormyridae				-
		X		-
Mormyrus kannume				
		X		
Gnathonemus lonibarbis				
		X		
Marcusenius victorae				
Mochokidae				-
		X		-
Synodontis afrofischeri				
Centropomidae				-

ates niloticus		X		-
Characidae				-
Brycinus sadleri		X		-
Brycinus.jacksonii		X		-

Table 3. Fish species composition and distribution in dams of Lake Victoria basin, Kenya

TAXA	DAMS														
Cyprinidae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Barbus apleurogramma	X	X	X	X	X		X		X		X	X	X	X	X
Barbus paludinosus		X		X		X	X		X	X	X	X	X	X	X
Barbus kerstenii	X			X					X		X	X		X	
Barbus neumayeri	X						X				X	X			
Barbus cercops									X		X			X	X
Barbus tripilospleura															X
Barbus jacksonii								X							
Barbus sp.											X				
Labeo victorianus								X	X						
Cichlidae															
Oreochromis niloticus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oreochromis esculentus	X		X	X	X										
Oreochromis variabilis	X	X			X										
Oreochromis leucostictus					X						X	X	X	X	
Tilapia rendalli											X			X	
Haplochromine spp.	X	X		X	X	X						X			
Astatotilapia nubilus	X		X		X										
Xystichromis phytophagous	X		X												
Pseudocrenilabrus multicolor		X		X	X	X									

Clariidae															
Clarias gariepinus		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Clarias liocephalus															X
Protopteridae															
Protopterus aethiopicus										X				X	
Mastacembelidae															
Mastacembelus frenatus												X			

KEY**;** **1**.Ugege**,** **2**.Mauna**,** **3**.Mwer, **4**.Ulanda, **5**.Kalenjuok **6**.Uranga**,** **7**.Ufinya,

8.Oyombe, **9**.Kosigah, **10**.Migowa**,** **11**.Uriri, **12**.Stella, **13**.Olasi**,** **14**.Kokech, **15**.Ratang

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Applicability and effectiveness of some fishing gears in assessing fish diversity and richness in non-trawlable areas of Lake Victoria (Tanzania)

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Abstract

Three exploratory surveys which mainly targeted information on fish species richness and diversity were conducted in November/December 2000, March/April 2001 and July/August, 2001, during short rains, long rains and dry period, respectively. The effectiveness of different fishing techniques in assessing fish diversity and richness in different habitats is discussed. Complementality of three techniques to yield both spatial and temporal spectra in species richness and diversity is demonstrated and conservation measures are recommended.

Key words: Species richness, fish diversity, gill-nets, beach-seine, electrotaxis, DC-electric fisher.

Introduction

Tanzania is among one hundred and fifty seven countries which signed and adopted the Convention on Biological Diversity (CBD) at the Earth Summit in Rio de Janeiro in 1992. Tanzania ratified the Convention in 1996. The CDB provides for global consensus for contracting parties to conserve biodiversity, sustainably utilize biodiversity and promote equitable measures of sharing benefits accrued from conservation.

Conservation in Lake Victoria is at its infancy stage and has to be intensified especially with the aftermath of Nile perch colonization since the 1980's. A drastic decline in biomass of several species and shrinkage in biodiversity has been evident and some species are feared extinct (Ogutu-Ohwayo, 1990b ; Witte *et al*., 1992 a&b ; Witte *et al*., 1995a; Seehausen, 1998). Predation by Nile perch is the primary cause assossiated to the decline than overfishing (Getabu, 1988 ; Goudswaard and Ligtvoet,1988 ; Barel *et al*.,1991 ; Craig, 1992 ; Kaufman, 1992 ; Gophen *et al*., 1995 ; Wanink, 1998). Whilst it is believed that species which survived predation took refuge in non-trawlable littoral microhabitats (Witte *et al*., 1992), the status of biodiversity has surprisingly remained uncertain. This has acted as a stumbling-block against some conservation measures that call for scientific evidences.

Considering the published East African criteria for choice of what to conserve by Howard (1994), IUCN (1994), neither information on species values (Habitats/areas supporting rare/endangered, endemic and flagship species) nor Communities and population values (areas with high populations of species or diversity of species) is available. This gap in information especially on species richness/diversity, habitat diversity and related effective sampling of the littoral non-trawlable areas in Lake Victoria (Tanzania) has necessitated the undertaking of baseline surveys by TAFIRI to address the problem. This study which was conducted under Lake Victoria Environmental Project (LVEMP) utilized a DC-electric fisher, multimeshed gill-nets and a beach-seine.

Among others, the objective of this study were: (a) to make an inventory of the threatened species and map-out habitats occupied by these species for conservation (b) assess habitat diversities and techniques for their effective sampling and (c) make recommendations to consolidate monitory and conservation measures.

Materials and methods

Study Area

Sampling was restricted to the littoral non-trawlable area of the lake, mostly in bays and gulfs shallower than 5m in depth. The areas are fringed with rocky, muddy, sandy or vegetated beaches or habitats. Some areas covered portions of the selected rivers. The areas covered (Fig. 1) include Shirati bay, Mori bay, Mori river, Mara bay, Mara river and Grants bay in sampling zone one (SZ1). Other areas include Speke gulf in sampling zone two (SZII), Mwanza gulf in sampling zone three (SZIII), Emin Pasha gulf in sampling zone four (SZIV) and Rubafu baya/Kagera river in sampling zone five (SZV).

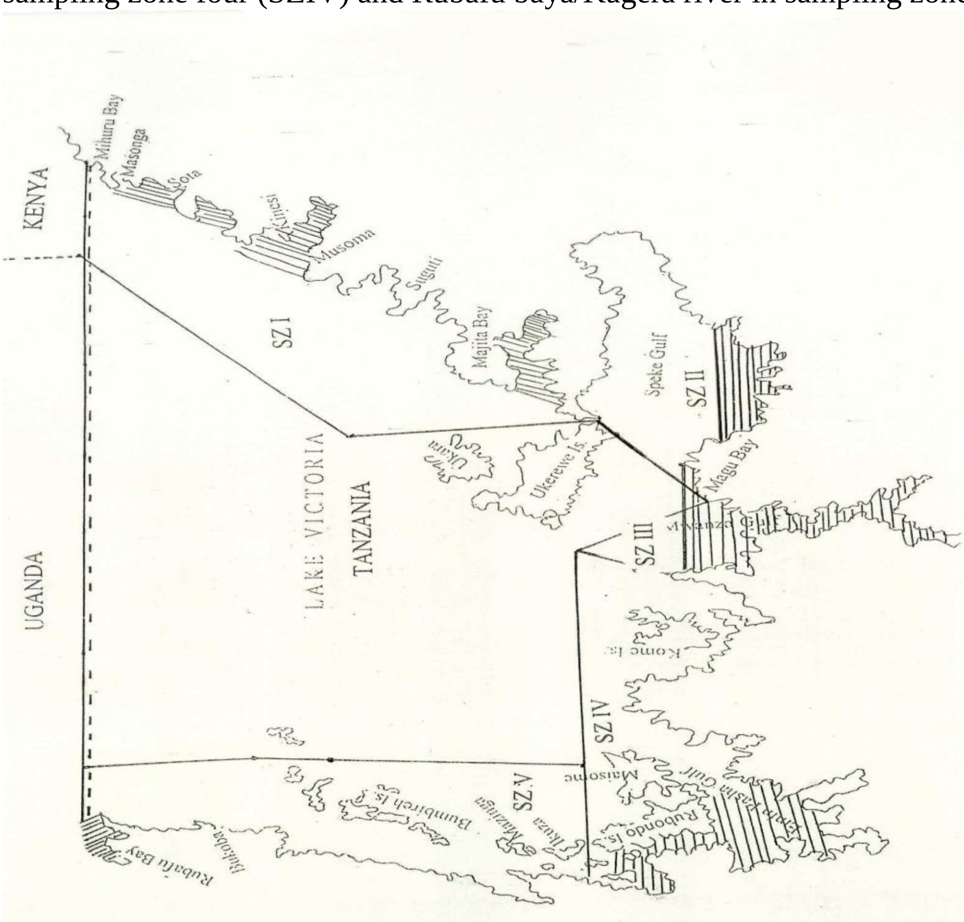
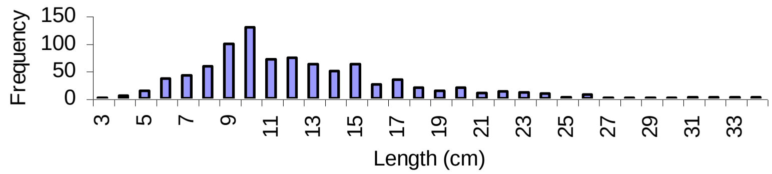


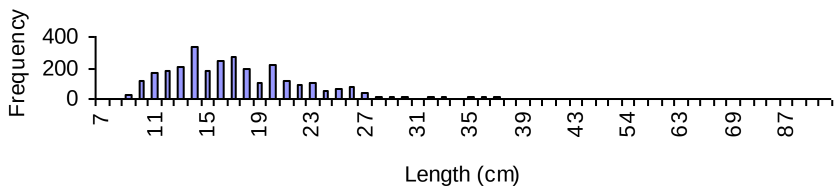
Fig. 1.1: Map of Lake Victoria (Tanzania) showing the study area.

Sample Collection

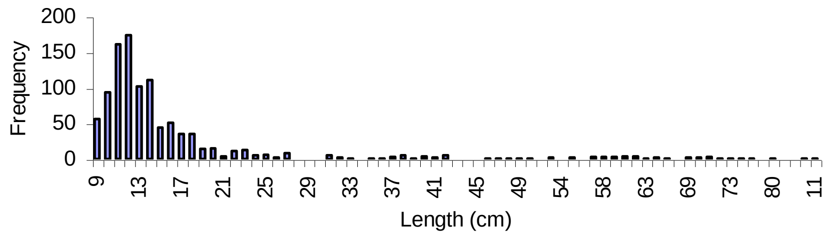
Acquisition of samples utilized a portable electric fishing system WFC7-HV, a beach-seine and multi-meshed gill-nets



Length-frequency distribution of *L.niloticus* from the survey conducted in Mwanza Gulf - November to December,2000



Length-frequency distribution of *L.niloticus* from the survey conducted in Emin Pasha Gulf - November to December,2000



Length-frequency distribution of *L.niloticus* from the survey conducted in Rubafu Bay - November to December,2000

Fig.2: Length frequency distribution of *Lates niloticus* in Mwanza gulf,Emin Pasha gulf and Rubafu bay based on beach-seine samples collected during November to December 2000

The electric fishing system (Fig. 2) was comprised of a GB-Generator Type HXMB.3.5, a control box, a transformer, a cathode and two anode controls with rings of sizes 320mm and 400mm in diameter. The generator operated at an output voltage of 230/240 VAC and fishing used both smooth and pulsed DC at the generator current of less than 10 amps. The control box and the transformer of the system were capable of converting the AC to a maximum output of 600-700 volts DC. The interconnected system was mounted in a wooden flat-bottomed boat, both being a poor conductor of electricity and capable of accessing shallow inshore habitats. The boat was propelled by a 25Hp outboard engine, ensuring that both cathode and anode electrodes of the system were maintained at 2m apart as the 'effective zone' during fishing. The system attracted fish out of their habitats (electrotaxis) which moved fast to the anode (anodic galvanotaxis) where they were brailed out of water by a small scoop net. This operation which was conducted in Shirati bay, Mori bay, Grants bay, Emin Pasha gulf and Rubafu bay necessitated a minimum of four members of the crew for effective fishing.

A beach-seine was 60m long with cod-end and wing mesh sizes of 1 and 3 inches, respectively. The net was provided with towing ropes of 100m in length and operated by 8-10 members of the hired crew in each area. Multi-meshed gill-nets used in this study consisted of nylon and monofilament nets which were set separately. Nets of 1, 1.5, 2,2.5, 3, 4, 5, 6, 7, and 8 inches in mesh size were used.

Both beach-seining and gill-netting in each area used either wooden or fibreglass canoes, mounted with a 25Hp engine. Usually gill-nets were set at 1800 hrs and retrieved at 0600 hrs unlike a beach-seine which was operated from 0600 hrs to about 1600 hrs. Whilst gill-netting was attempted in all habitat types (rocky, muddy, vegetated, sandy and riverine), the beach-seine was restricted in only sandy, muddy and vegetated habitats. In rivers, gill-nets were set across when the river current was considered low or moderate. At high current, however, the nets were either set along river banks, tied to some vegetation, or were set and allowed to drift relative the fishing canoe.

Sampling in each area was kept to a minimum of 2 days and a maximum of 4 days, depending on the size of the area. Usually landed catches were sorted into species using the LVFRP species identification guide (Okaranon *et al*., 1997). Length and weight for individuals of each species were taken using a one-metre ruler and a pan/electronic scale, respectively. Whilst lengths were measured to the nearest of 0.1cm, weights were recorded to within 0.2kg accuracy. Individuals of each species were eventually counted and data recorded in appropriate forms for subsequent preservation by a desk computer.

Data Analysis

Both species composition, length frequencies and diversity indices were done using statistical programmes in Windows 2000 MS Excel. Whereas species richness (density) was obtained as the species counts, species diversity which combines both species richness and their relative importance in terms of abundance was derived as Shannon-Wiener Diversity Index (H^I) of the form:

$$H^I = - \sum_{i-1}^{S} Pi \log Pi \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Where: S = number of species in the sample
Pi = relative importance values obtained as the squared ratio of ni - the importance value of s individual species to N – the total importance value for all species in the sample.

Results

Habitats and Effectiveness of Gears

Catch Composition by Gear Type

Catch composition of the major fish species is illustrated in Table 1. Contributions by different gears for the same species and during the same time scale differed greatly and comparatively highest values of composition by *L. niloticus*, *O. niloticus* and Haplochromines were amenable to beach-seining. *L. niloticus* composed beach-seine catches by 61.3%, 78.9% and 42.3% during the short rains, long rains and dry period, respectively. During the same period, the same species comprised gill-net catches by 49.5%, 35.9% and 23.7%, respectively. *O. niloticus* during the short rains, long rains and dry period comprised beach-seine catches by 14.4%, 8.9% and 33.7% compared to 16%, 14.9% and 5.2% for gill-net catches, respectively. Haplochromines comprised catches amenable to electric fishing, beach-seining and gill-netting during the long rains by 68.4%, 6.9% and 2.1%, respectively.

Table 1: Catch composition of the major fish species by gear type based on non-trawlable area surveys of November/December 2000, March/April 2001 and July/August 2001.

	%ge CATCH COMPOSITION BY WEIGHT								
MAJOR FISH SPECIES/GROUPS	**ELECTRIC FISHING**			**BEACH SEINING**			**GILL-NETTING**		
	SR	**LR**	**DP**	**SR**	**LR**	**DP**	**SR**	**LR**	**DP**
1. *L. Niloticus*	-	1.3	-	61.3	78.9	42.3	49.5	35.9	23.7
2. *O. niloticus*	-	23.0	-	14.4	8.9	33.7	16.0	14.9	5.2
3. *Haplochromines*	-	68.4	-	15.9	6.9	11.5	5.0	2.1	23.3
4. Others	-	7.3	-	8.4	5.3	12.5	29.5	47.1	47.8
		100%		100%	100%	100%	100%	100%	100%

KEY:
SR = Short Rains
LR = Long Rains
DP = Dry Period

Species Density by Habitat Type

The actual species counts collected from each habitat by individual gears, expressed as percentage of the total collection are illustrated in Table 2. The results show that individual gears were effective in certain ranges of habitats. Electric fishing samples constituted many species at the tune of 55% and 45% from rocky and vegetated habitats, respectively. Whilst no collections were made from open sandy bottoms, electric fishing in muddy bottoms and riverine environments was not attempted.

Table 2: Effectiveness of sampling gears in different habitats, expressed as percentage of the actual collection in a given habitat of interest to the total as based on the non-trawlable area surveys of November/December 2000, March/April 2001 and July/August 2001

		HABITAT TYPES					
NO.	**GEAR TYPE**	**SANDY**	**MUDDY**	**ROCKY**	**VEGETATED**	**RIVERINE**	**TOTAL**
1.	Electric Fishing	0%	NA	55%	45%	NA	100%
2.	*Beach-seining*	40%	35%	DZ	25%	DZ	100%
3.	*Gill-netting*	18%	30%	13%	9%	30%	100%

KEY:
DZ = Dead Zone
NA = Not Assessed

Beach seining registered a good collection from both sandy and muddy habitats to the tune of 40% and 35%, respectively. Vegetated bottoms yielded only 25% of the species density while rocky and riverine habitats are dead zones which could not be accessed by the gear. Gill-nets were operated in all habitats, showing promising collections from muddy and riverine habitats to the tune of 30% in both habitats. Sandy, rocky and vegetated habitats registered collections to the tune of 18%, 13% and 9%, respectively.

The distribution of species in different habitats and at different seasons as based on collections by different gears is shown in Table 3. These results show that the distribution of the species and the nature of habitats affected the effectiveness of the gears. *Lates niloticus*, *O. niloticus* and Haplochromines were distributed in all habitats and the three sampling gears therefore accessed them. Some species were distributed in a wide range of habitats such as muddy, sandy and riverine habitats. These were captured by gill nets only despite their being in some habitats, which were well accessed by a beach-seine (muddy and sandy bottoms). This category of species distribution consisted of *Synodontis victoriae* and *Marcusenius rheni* (gilled from sandy, muddy & riverine habitats), *Bagrus docmak*, *Petrocephalus catostoma* and *Mormyrus kannume* (gilled from both muddy and riverine habitats), *Aethiomastacembelus frenatus* (gilled from muddy habitats), *Gnathonemus longibarbis* and *Hippopotamyrus grahami* (gilled from riverine habitats). *Tilapia rendalli* (captured from sandy, muddy and vegetated bottoms) falls in the category of species which appeared in only beach-seine catches. The species was never captured by gill-nets during the three seasonal surveys. Another category of species consisted of *Schilbe intermedius*, *Synodontis afrofischeri*, *Labeo victorianus*, *Brycinus sadleri* and *Brycinus jacksonii* which were more vulverable to both gill-nets and a beach-seine during the long rains than any other time. These are anadromous species, which were found distributed in a wide range of habitats.

The only species captured by the electric fisher consisted of *Barbus* spp. (rocky shore), *Clarias gariepinus* (rocky & vegetated bottoms), *L. niloticus* (rocky and vegetated bottoms), *O. niloticus* (rocky bottom), *R. argentea* (rocky), *Protopterus aethiopicus* (vegetated bottom) and Tilapia zillii (vegetated bottom).

Table 3: Collection of species from different habitats by different gears during surveys of non-trawlable areas in Lake Victoria (Tanzania), conducted in November/December 2000 (Short Rains) and March/April 2001 (Long Rains)

SPECIES NAME	PERIOD	SAMPLES BY ELECTROTAXIS					BEACH-SEINE SAMPLES					GILL-NET SAMPLES				
		S	**M**	**RI**	**RO**	**V**	**S**	**M**	**RI**	**RO**	**V**	**S**	**M**	**RI**	**RO**	**V**
Barbus spp.	SR						+	+			o	+	+	+	o	
	LR	o			+	o	o	o			+	o	o	o	o	o
Brycinus jacksonii	SR					o	+	+			o	+	+	+	o	
	LR						+	+			o	+	+	+	+	+
Brycinus sadleri	SR					o	+	+			+	+	+	+	+	
	LR	o			o	o	+	+			+	o	+	+	+	+
Bagrus docmak	SR						o	o			o	o	+	o	o	
	LR	o			o	o	o	o			o	o	o	+	o	o
Clarias gariepinus	SR						+	+			o	+	o	o	o	
	LR	o			+	+	+	+			o	o	+	+	+	o
Hippopotamyrus	SR						o	o			o	o	o	o	o	o
Grahami	LR	o			o	o	o	o			o	o	o	+	o	o
Haplochromines	SR						+	+			+	+	+	+	+	
	LR	o			+	+	+	+			+	+	+	+	+	o
Labeo victorianus	SR						+	+			+	o	+	o	o	
	LR	o			o	o	+	+			o	+	+	+	o	o
Lates niloticus	SR						+	+			+	+	+	o	+	
	LR	o			+	+	+	+			+	+	+	+	+	+
Mormyrus kannume	SR						o	o			o	o	+	o	o	
	LR	o			o	o	o	o			o	o	+	+	o	o
Marcusenius victoriae	SR						o	o			o	o	o	o	o	
	LR	o			o	o	+	o			o	o	o	o	o	o
Marcusenius rheni	SR						o	o			o	+	+	+	o	
	LR	o			o	o	o	o			o	o	o	+	o	o
Aethiomastacembelus	SR						o	o			o	o	o	o	o	o
frenatus	LR	o			o	o	o	o			o	o	+	o	o	o
Oreochromis	SR						+	+			+	0	+	0	0	
Leucostictus	LR	0			0	0	+	+			+	0	+	+	+	0
Oreochromis	SR						+	+			+	+	+	o	+	
Niloticus	LR	o			+	o	+	+			+	o	+	+	+	+
Petrocephalus	SR						o	o			o	o	+	+	o	
Catastoma	LR	o			o	o	o	o			o	o	o	+	o	o
Protopterus	SR						+	o			o	+	+	o	o	
Aethiopicus	LR	o			o	+	+	o			o	o	+	+	o	o
Rastrineobola	SR						+	o			+	o	o	o	o	
Argentea	LR	o			+	o	+	o			+	o	o	o	o	o
Synodontis	SR						+	+			o	o	+	o	o	
Afrofischeri	LR	o			o	o	+	+			o	+	+	+	o	+
Synodontis	S R						o	o			o	+	+	+	o	
Victoriae	LR	o			o	o	o	o			o	+	+	+	o	o
Schilbe	SR						o	+			o	+	+	+	o	
Intermedius	LR	o			o	o	o	o			o	+	+	+	+	+
Tilapia rendalli	SR						+	+			+	o	o	o	o	
	LR	o			o	o	+	+			+	o	o	o	o	o
Tilapia zillii	SR						+	+			+	o	o	o	+	
	LR	o			o	+	+	+			+	o	+	+	o	o
Gnathonemus	SR						o	o			o	o	o	+	o	
Longibarbis	LR	o			o	o	o	o			o	o	o	o	o	o

KEY:
S = Sandy; RI = Riverine; V = Vegetated; LR = Long Rains
M = Muddy; RO = Rocky; SR = Short Rains

Dead Zone or Not Accessed

Size Composition

The collected samples by electric fishing indicate a size structure of 6-12cm, 21-23cm, 38cm, 19cm and 20cm for *O. niloticus*, *C. gariepinus*, *P. aethiopicus*, *L. niloticus* and *T. zillii*, respectively. Length frequency distribution for *O. niloticus* (Fig. 3) indicates a normal distribution with three modes at 8cm, 11cm and 19cm. The observed sizes for individual of the species confirm that samples from electric fishing were composed of juvenile fishes, save for *T. zillii*. However, individuals of less than 6cm were not observed.

Samples of *O. niloticus* collected by a beach-seine from Shirati bay, Mori bay and Mara bay had the size structure of 1-41cm, 2-10cm and 2-41cm, respectively. The observed modal sizes for the respective area collections (Fig. 4) were 3cm, 5cm and 8cm. Whilst immature individuals dominated the catch, juveniles of less than 6cm were well represented unlike the samples collected by the electric fisher. Samples of the same species which were collected by gill-nets in the same areas fished by a beach-seine indicate a size structure of 9-33cm. Again juveniles of bellow 9cm are not represented.

Species Richness/Density

Table 4: Spectrum of the species richness by area for combined gears during the surveys of Oct/Nov. 2000 (Short Rains), March/April 2001 (Long Rains) and July/August, 2001 (Dry Period).

a. Bays and Gulfs

Period	Shirati Bay	Mori Bay	Mara Bay	Grants Bay	Speke Gulf	Swanza Gulf	Emin Pasha	Rubafu Bay
Short rains	6	10	8	12	-	19	13	12
Long rains	6	10	14	9	9	14	13	13
Dry period	5	9	12	8	9	10	9	7

b. Rivers

Period	Mori river	Mara river	Kagera river
Short rains	13	8	4
Long rains	12	4	10
Dry period	13	8	4

Table 4 indicates the distribution in species richness for different areas and during the three sampling periods. Total counts of 24, 22 and 22 species were yielded during the long rains, short rains and dry period, respectively. A general trend in the shift of species richness from high during the wet season (SR & LR) to low during the dry season (DP) is depicted in all the sampling areas, fairly pronounced in Mwanza gulf, Emin Pasha gulf, Rubafu bay, Mara and Kagera rivers. The observed distribution in species density for Shirati bay (SR = 6, LR = 6 & DP = 5), Mori bay (SR = 10, LR = 10 & DP = 9), Mara bay (SR = 8, LR = 14 & DP = 12), Grants bay (SR = 12, LR =9 & DP = 8), Speke gulf (LR = 9 & DP = 9), Mwanza gulf (SR = 19, LR = 14 & DP = 10), Emin Pasha gulf (SR = 13, LR = 13 & DP = 9) and Rubafu bay (SR = 12, LR = 13 & DP = 7) is somewhat on the high side during the long rains, especially in bays which are influenced by big rivers (Mara bay and Rubafu bay). Whilst Mori river indicates somewhat a consistent distribution in species density (SR = 13, LR = 12 & DP = 13) both Mara river (SR = 8, LR = 4 & DP = 8) and Kagera river (SR =4, LR = 10 & DP = 4) show dramatic temporal changes in species density.

Though not linearly yet a pattern of increasing species richness from sampling zone one towards sampling zone five is demonstrated over the entire time scale (from short rains to dry period). Altogether, Mwanza gulf (SR = 19, LR = 14 & DP = 10) and Mori river (SR = 13, LR = 12 & DP = 13) yielded the highest species richness.

Species Diversity

Table 5: Shannon-Wiener species diversity indices for different sampling areas during November/December 2000 (Short Rains), March/April 2001 (Long Rains) and July/August 2001 (Dry Period).

AREAS		Shirati Bay	Mori Bay	Mori River	Mara Bay	Mara River	Grants Bay	Speke Gulf	Mwanza Gulf	Emin Pasha	Rubafu Bay	Kagera River
	H^I	0.549	0.707	0.614	-	0.501	0.803	-	0.693	0.542	0.447	0.332
SR	H^I	0.127	0.610	0.639	0.615	0.442	0.676	0.445	0.503	0.747	0.476	0.857
DP	H^I	0.326	0.720	0.880	0.646	0.538	0.538	0.628	0.611	0.584	0.477	0.474

KEY:
SR = Short Rains
LR = Long Rains
DP = Dry Period
H^I = Shannon-Wiener Diversity Index

Shannon-Wiener species diversity indices which are only based on gill-net collections are illustrated in Table 5. High fluctuations in species diversity were observed in Kagera river (H^I SR = 0.332, H^I LR = 0.857 & H^I DP = 0.474), Mara river (H^I SR = 0.501, H^I LR = 0.442 & H^I DP = 0.646) Mori river (H^I SR = 0.614, H^I LR = 0.639 & H^I DP = 0.880) and Shirati bay (H^I SR = 0.549, H^I LR = 0.127 & H^I DP = 0.326). The rest of the areas indicate very consistent diversity indices, only varying slightly among seasons.

Discussion

Habitats and Effectiveness of Sampling Gears

Rocky and vegetated bottoms or fringes in the inshore littoral waters of Lake Victoria form very important habitats, which harbour a diverse fish species. Collections by gill-nets, angling rods and scuba diving gear indicated that by far the largest number of surviving species (after the impact of predation by Nile perch) within the rocky shore habitats in Mwanza gulf and Speke gulf were an assemblage of more than 100 scientifically new species (Seehausen *et al*., 1997b and Seehausen, 1999). Fryer and Iles (1972), using gill-net catch data by Gee (1966) demonstrated that inshore muddy, sandy gravel and rocky bottoms were inhabited by many non-predator species as predators appeared in semi-open/surface waters. This implies that colonization of rocky and vegetated shores by a diverse fish species could be more linked to avoidance of predators, among other ecological factors.

This study confirms that both rocky and vegetated habitats in the littoral non-trawlable areas of the lake do harbour a large assemblage of species, yielding 55% and 45% of the collections by electric fishing, respectively. Beach-seine samples yielded 25% of the species count from vegetated habitats and gill-net samples yielded 13% and 9% of the collections from rocky and vegetated habitats, respectively. Note that species counts in the two habitats would have been a lot higher than indicated if haplochromines were identified to species level.

It is also demonstrated by this study that electric fishing was effective in sampling rocky and vegetated habitats in which 68% of the catch was comprised of haplochromines. A beach-seine was effective in sampling of both sandy and muddy habitats yielding 40% and 35% of the collections, respectively. Gill-nets were effective in taking samples from both muddy and riverine habitats.

The effectiveness of electric fishing is promoted by the ability of the gear to attract fish out of the crevices and vegetation by electrical stimulation known as electrotaxis. This, however, is governed by the right choice of equipment. DC electric fishers when operated at fairly low voltages induce good electrotaxis or galvanotaxis with little or no damage to fish as the direct current only stimulates body cells and fish muscles (Lamarque, 1990). This is contrary to AC-electric fishers, which act on fish nerve fibres causing tetany to fish and eventual mortalities due to vertebral malformation (Klein, 1967; Spencer, 1967; Lamarque, 1990).

One of the observed limitations of this technique was the lack of representation for juveniles of less than 6 cm in the sample which may be associated to size selectivity of the gear(Fig. 3). Studies by Junge and Libosvarsky, (1965) indicated that juveniles and small sized fish as a whole have a lower probability of capture than larger individuals under comparable conditions. This is because large individuals have larger nerve cells and muscles, which promote greater electrical stimulation. The other limitation of electric fishing is that no samples were collected from clear sandy habitats probably due to fish avoidance behaviour for the approaching vessels as reported by Zelewski and Cowx (1990).

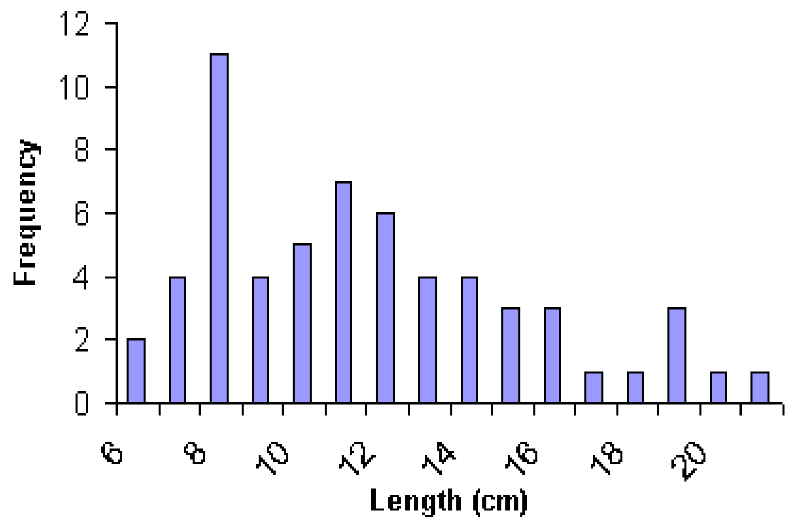
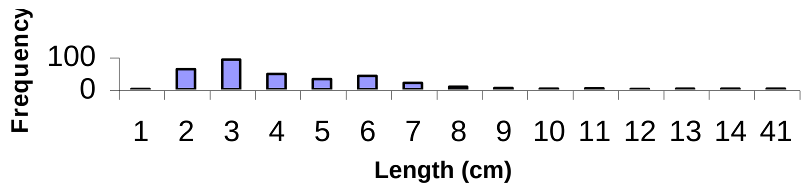


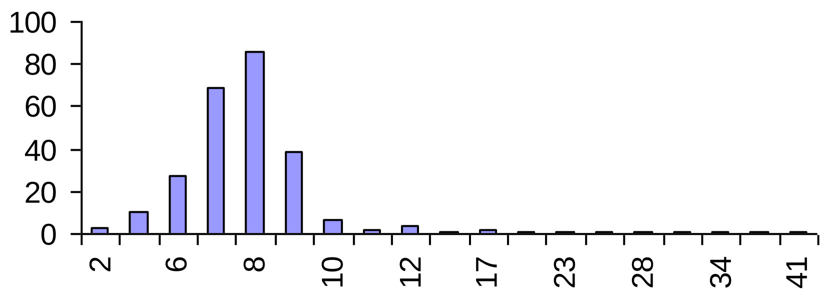
Fig.3 Length frequency distribution of O.niloticus as based on Electrical Fishing Data, March to April 2001

The effectiveness of a beach-seine is more reflected in the high sample sizes of the collections and representative samples for all sizes, especially for those between 1-10cm (Fig.4). Somewhat higher and more reliable catch composition values obtained by a beach-seine than other gears for the abundantly distributed species in all the habitats (*L. niloticus*, *O. niloticus* and Haplochromiens) attests for the effectiveness of the gear as well. These attributes of the gear are as a result of its characteristics, i.e. being active and non-selective. The capture of *Tilapia rendalli*, the only species captured by a beach-seine and not any other gear, further demonstrates the ability of the gear to fish in very shallow areas with a good vegetation cover where the species has been reported to dwell by many authors including Witte and Van Densen (1995).

The limitation of the gear in capturing some species in muddy or even sandy bottoms (accessible areas) as noted for *S. victoriae*, *M. rheni*, *M. kannume* and *A. frenatus* is probably more related to fish behaviour than other factors. Witte and Van Densen (1995) and Okaranon *et al*. (1997) described the habitats of these species as mostly being soft bottoms, usually swampy. Being in such habitats, the species are capable of avoiding the foot-rope by diving into the mud especially if the foot-rope is not provided with adequate sinckers. The major limitation of this gear is that species distributed in rocky or riverine habitats may not be represented in beach-seine catches since the two habitats are dead zones, inaccessible by the gear.



Length frequency distribution of *O.niloticus* in Shirati Bay based on beach seine samples collected during March-April,2001



Length frequency distribution of *O.niloticus* in Mara Bay based on beach seine samples collected during March-April,2001

Fig. 4: Length frequency distribution of Oreochromis niloticus in Shirati, Mori and Mara Bay based on beach seine samples collected during March – April, 2001

Gill-nets are usually passive gears. As a result, their effectiveness depend on the mobility or agility of the species. Nets of relatively small ply, mesh size and inconspicuous colour to fish are very effective (Fryer and Iles, 1972). This explains why some species which avoid active gears like a beach-seine are easily captured by gill-nets. Under this study gill-nets have demonstrated their effectiveness in catching anadromous species during their seasonal influx in rivers for spawning in March/April (Long Rains).

Capable of catching fish in all habitats, the gear is size selective, collecting fewer samples which may lead to skewed distributions (Asila, 1999) or missing some of the species. Multimeshed nets, however, may reduce this limitation. In conducting biodiversity studies caution should be taken to optimise the collection of representative samples in all habitats. Since no single method is capable of this, it is recommended that several techniques which complement one another should be employed. Choice of electric fishing, gill-netting and beach-seining for this study is an example which has yielded promising results. It should therefore be extended for riverine sampling which calls for multidisciplinary action.

Species Richness and Diversity
The littoral non-trawlable area seems to harbour many species than what has been estimated by this study because no attempt was made to classify haprochromines to species level due to the lack of a species guide. Nevertheless, since the estimate of species count in trawlable habitats is 13-14 species (Mkumbo, 1999; Chande and Mhitu, 2001) it follows that many of the remaining species occupy the non-trawlable habitat as a refugia, apart from spawning and nursery functions. High species count during the wet season than the dry season may be attributed by spawning whereby most anadromous species tend to move upstream for spawning. This is reflected by an increase in diversity indices both for Kagera river and Mori river. In Mara river where species richness and diversity decreases considerably during the long rains may suggest the influence of pollutants from upstream and thus the lack of spawning activity upstream. The low species diversity in Shirati bay during the long rains may be due to limited food organisms in the area, resulting to a decline in species abundance. The bay lacks the influence of big rivers whereby allochthonous inputs from rivers may stimulate localized productivity, thus promoting high species diversity.

The trend of increasing species richness or density as one moves from sampling zone one towards sampling zone five is more related to distribution of diverse habitats and microhabitats in the area. The number of rocky shores and rivers, for example tend to increase as one moves from Shirati bay towards Emin Pasha gulf and Rubafu bay. Both Mwanza gulf, Mori river and part of Mori bay are identified as biodiversity hotspots. In order to conserve the species assemblages in those areas, monitory surveys should aim at defining specific representative sites, taking into account of other values.

Conclusions
Following conclusions may be drawn from the results:

i. Rocky and vegetated bottoms or fringes in the inshore littoral waters of Lake Victoria form very important habitats which harbour a diverse fish species especially non-predator species.
ii. Electric fishing was found to be effective in sampling rocky and vegetated habitats, whereas a beach-seine was effective in sampling of both sandy and muddy habitats. Gill-nets were effective in taking samples from both muddy and riverine habitats.
iii. The effectiveness of electric fishing is promoted by the ability of the gear to attract fish out of the crevices and vegetation by electrical stimulation known as electrotaxis. However, electric fishing was its size selectivity which means juvenile and/or small sized fish have low probability of being caught by electric fishing.
iv. The beach-seine apart from being non-selective in size, it can be used to fish in very shallow areas with a good vegetation cover. However, it can not be effectively be used in muddy and sandy bottoms.
v. Gill-nets are capable of catching fish in all habitats. However, the gear is size selective.

vi. The littoral non-trawlable area seems to harbour many species than what has been estimated by this study.

Recommendations

i. In order to promote effective conservation of the identified biodiversity hotspots it is recommended that subsequent monitory research should be geared to address the problem of defining specific representative sites.
ii. The noted contributions of the major transboundry rivers to maintenance and sustenance of biological diversity in the lake basin as well as the observed fluctuations in fish diversity especially in Mara river and Kagera river prompts the need for intensified harmonized research in these rivers in order to maximize the health of the species and the lake at large.
iii. Since haprochromines are increasingly composing both trawlable and non-trawlable catches, it is recommended that subsequent research should develop haplochromines species guide for elaborate biological and fish diversity studies.
iv. In order to optimise the collection of representative samples from all habitats for biodiversity studies, it is recommended that several techniques which complement one another should be employed. Electric fishing, gill-netting and beach-seining techniques are highly recommended for the entire range of habitats. Extended use of the DC-electric fisher for riverine sampling should be tested.

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The potential of mukene (*Rastrineobola argentea*) fishery in Lake Victoria with suggestions for its management

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Abstract

Following the decline in catches of endemic fish species in Lake Victoria, Mukene, *Rastrineobola argentea* has become an important commercial fish species. The fishery spread first through Kenyan, and Tanzanian waters and is now well established in the Ugandan portion of the lake. *Rastrineobola*, together with the Nile perch and the Nile tilapia are the three most important commercially exploited fish species in Lake Victoria now. High mortality due to human exploitation and predation pressure by the Nile perch have contributed to changes in biological characteristics of mukene populations. Monthly samples of mukene covering at least a calendar year were obtained from the artisanal fishermen operating in Lake Victoria. These were analyzed for size structure, growth, gonad maturity state and breeding periodicity. Type and quantities of by-catch species and parasite infestation were also determined. Size structure of mukene populations has reduced from a mean of more than 60 mm SL in the early 1970's to 44 mm SL in 1997. A five or three mm-mesh net, which captures may immature fishes, has replaced a 1 mm mesh net. Catches from closed bays and near shore areas contain a high proportion of juvenile mukene, tilapia and Nile perch as by-catch. In the "islands" belt of Lake Victoria, where the bulk of mukene fishing occurs, high proportions of immature mukene is caught during the months of November/December. This is the time when young mukene are recruited into the fishery and should be closed to fishing. Considering the above changes to mukene populations in the lake, a 10-mm mesh net previously recommended for harvesting the species, may no longer be suitable. *R. argentea* should therefore be exploited away from the shore line and closed bays using nets with minimum mess size of 5 mm.

Key words: Rastrineobola, Lake Victoria, life parameters, exploitation

Introduction

Until about two decades ago, the fishery of mukene *Rastrineobola argentea* on the Ugandan side of Lake Victoria was not very important. The fishery was then based on the endemic tilapiines, *Oreochromis (Oreochromis) esculentus* g. and *Oreochromis (Nyasatilapia) variabilis* (B).; the catfishes, *Bagrus docmak (F.)* and *Clarias (Clarias) gariepinus* (B). and the lungfish *Protopterus aethiopicus (H)*. With the introduction and the subsequent establishment of foreign fish species, the Nile perch, *Lates niloticus* (L.) and the Nile tilapia, *Oreochromis (Oreochromis) niloticus* (L.), the indigenous species have almost disappeared from the catches. *R. argentea* is the only endemic species landed in significant quantities. It is second to the Nile perch in the Ugandan waters of Lake Victoria and coming up fast on Lake Kyoga. It is however not yet being fished on Lake Nabugabo. The species is exploited for both human consumption and animal feeds manufacture.

Increased pressure on Mukene has over time resulted in changes in the life history of the species. Such changes, therefore, require appropriate management measures for rational exploitation by the fishery. It has for example been recommended that *R. argentea* be fished with a 10 mm mesh size net. This was proposed at the beginning of the mukene exploitation on the Ugandan side of Lake Victoria before the species' biological parameters had stabilized. This paper outlines changes in biological parameters that have occurred to populations of *R. argentea* in the Ugandan sector of Lake Victoria following increased exploitation. In the light of these changes, appropriate management measures are suggested for further exploitation of the species.

Materials and methods

Monthly samples of *Rastrineobola argentea* were obtained from artisanal fishermen operating in Napoleon Gulf at Kikondo, representing a sheltered bay; Buvuma Channel at Lingira for the "islands" zone and the open water at Bugaia Island (Figure1), between January 1997 and April 1998. During each sampling, about 0.5 kg of mukene were randomly scooped from a freshly hauled catch and immediately fixed in 5% formaldehyde solution.

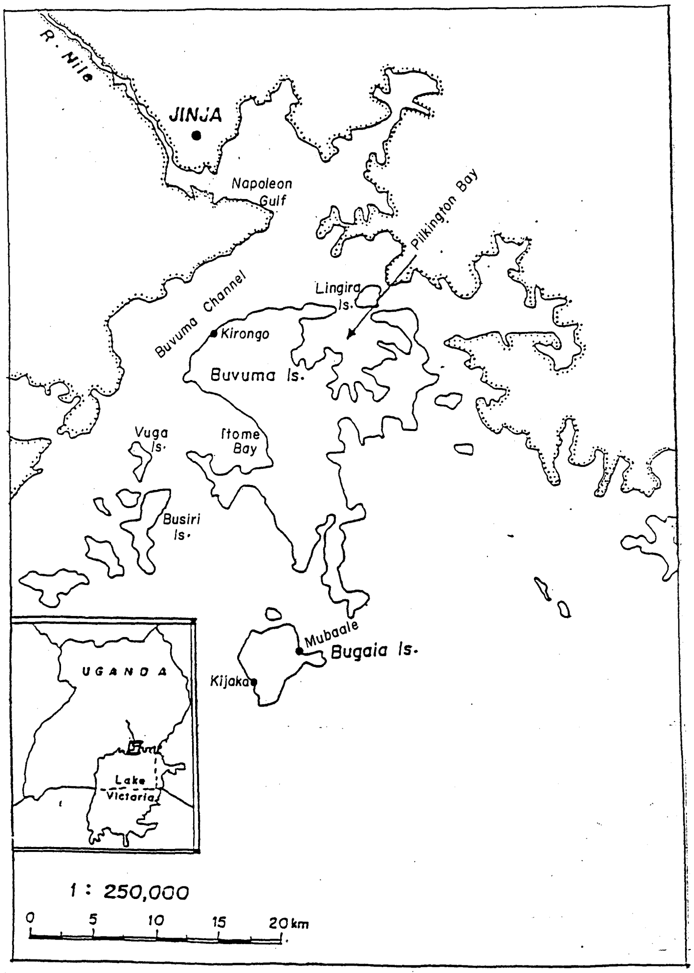

Figure 1. Map of Lake Victoria showing study area

In the laboratory, different fish species in the sample were identified, sorted counted and weighed to determine composition of by-catch. Standard lengths (in mm) of mukene were taken to determine length frequency distribution of the sample. Gonad maturity state of the fishes was determined as in Nikolsky (1963). Growth parameters were determined by subjecting length frequency data to computer analysis using ELEFAN software of Gayanilo *et al.* (1988). To compare population structures before and after the Nile perch upsurge in Lake Victoria, length measurements were also taken from a sample of mukene caught in August 1970 and stored in FIRRI museum.

Results

Length frequency distribution of populations of the species from Buvuma Channel showed an annual mean length of 44 mm SL as compared to 48 mm in 1988 and more than 60 mm SL in the 1970's (Figure 2).

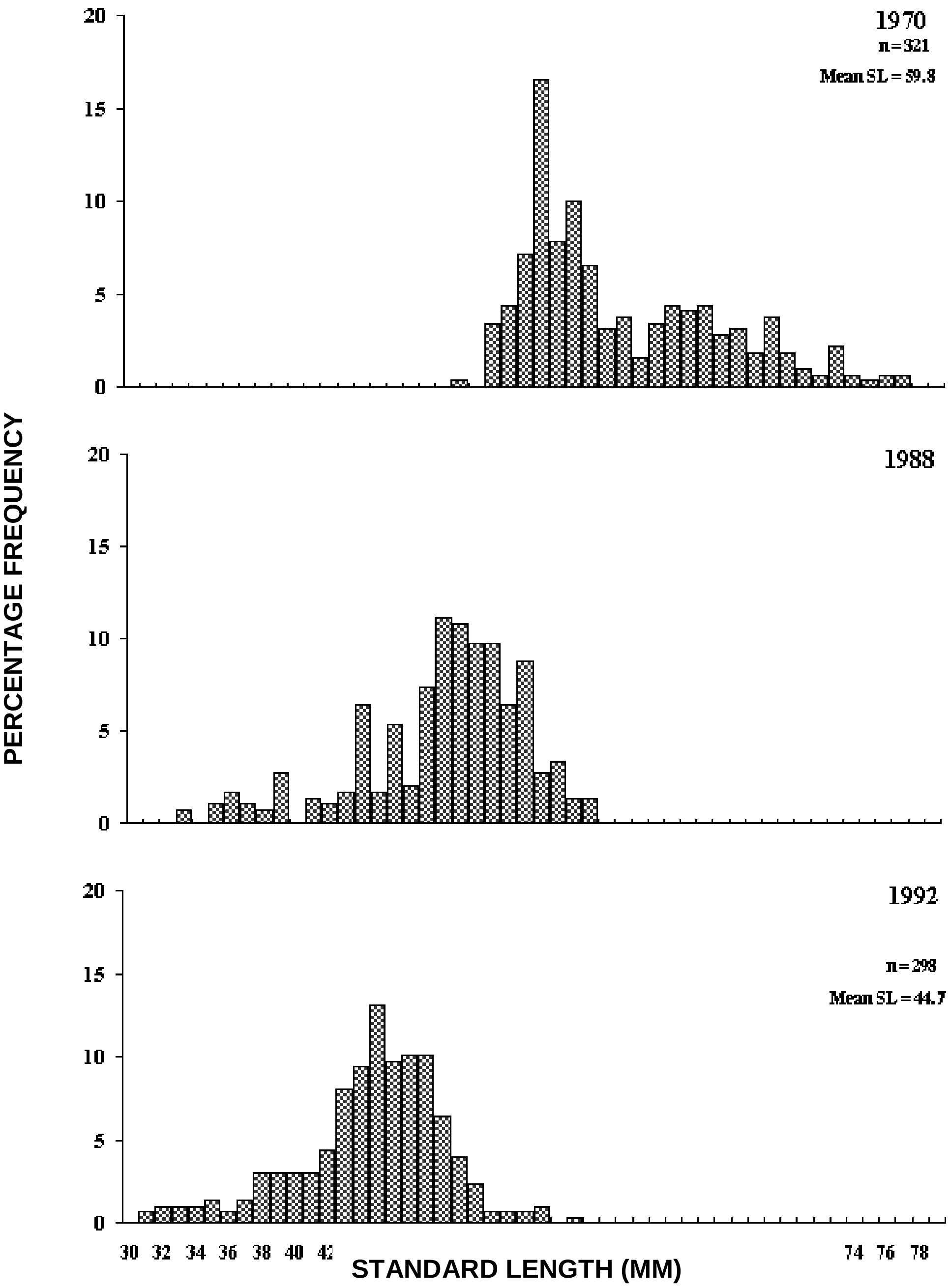

Figure 2. Length frequency distribution of *R. argentea* from Lake Victoria in 1970, 1988 and 1992

Size at first maturity in both Napoleon Gulf and Buvuma Channel was calculated at 41 mm SL for males and 42 mm for females (Figure 3). The Bugaia population however matured at a much smaller size of 36 mm SL (Figure 4). The three populations showed that 92.7% of the catch at Bugaia consisted of mature fishes while 68.8% and only 41.4% of mukene respectively in Buvuma channel and napoleon gulf were mature (Figure 5). While mukene was observed to breed throughout, peak breeding occurred twice a year, in August and in December / January (Figure 6). With the exception of the months July, August and January, the bulk (>50%) of the catch in Napoleon Gulf consisted of immature mukene. At Lingira only the months of November and December had more than 50% immature while at Bugaia very few immature mukene were recovered throughout the year (Figure 7).

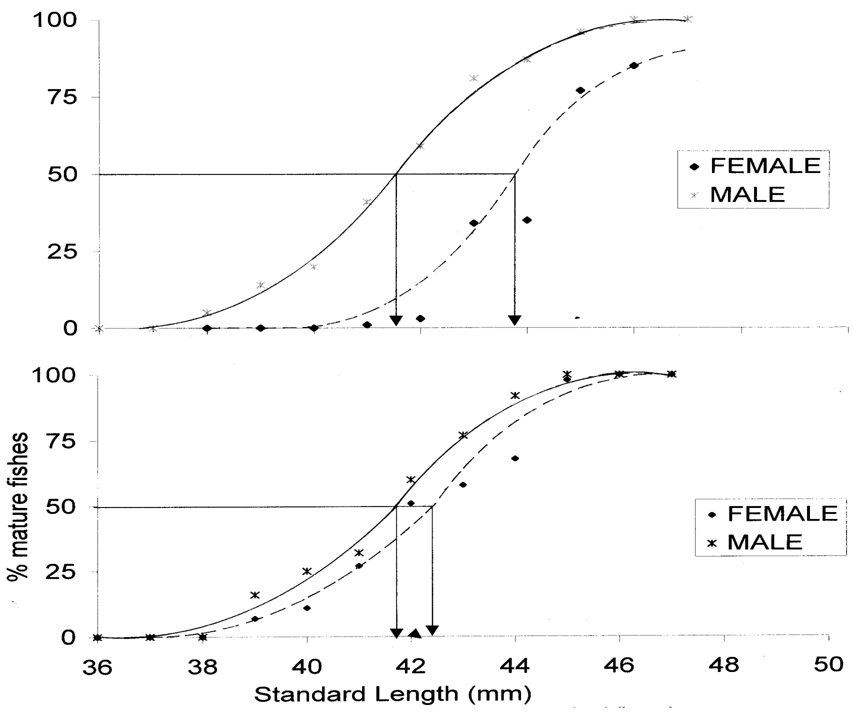

Figure 3. Size at first maturity of R. *argentae* from Lake Victoria, Jinja

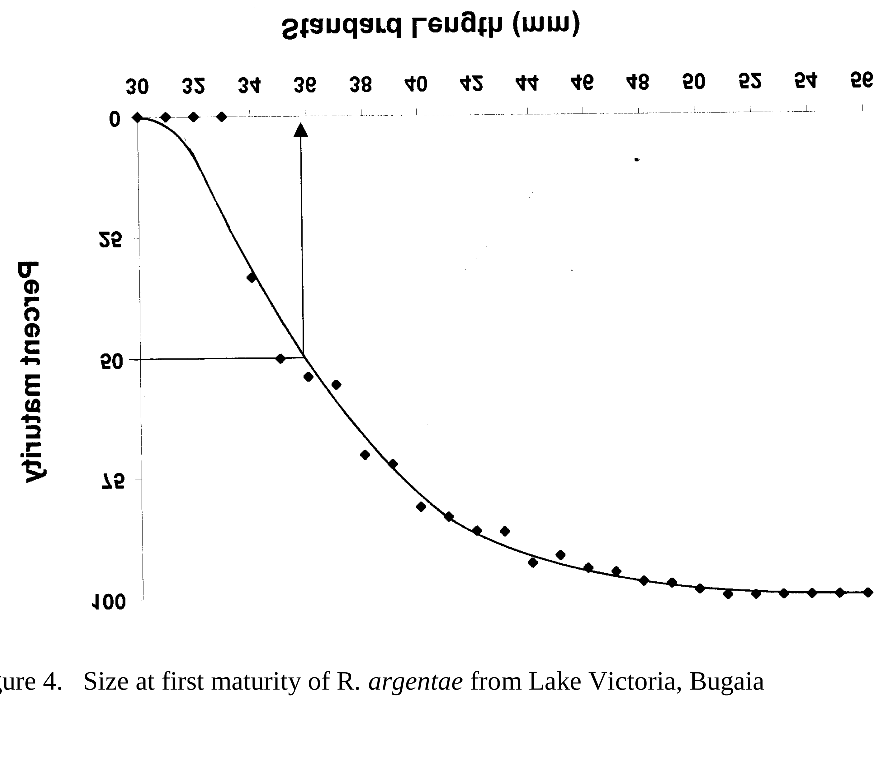

Figure 4. Size at first maturity of R. *argentae* from Lake Victoria, Bugaia

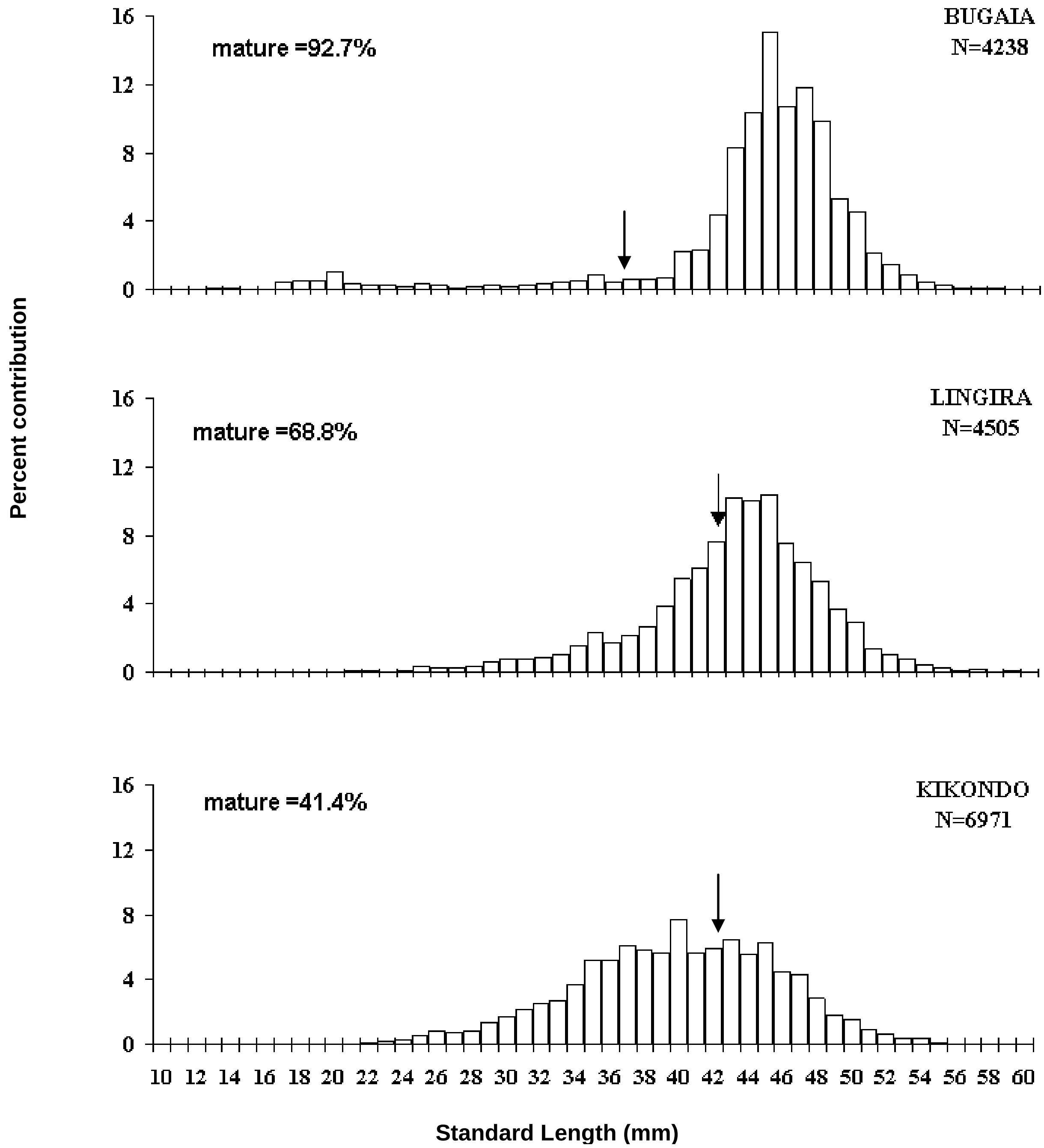

Figure 5. Length frequency distribution of *Rastrineobola argentea* caught in 5 mm mesh net from Lake Victoria

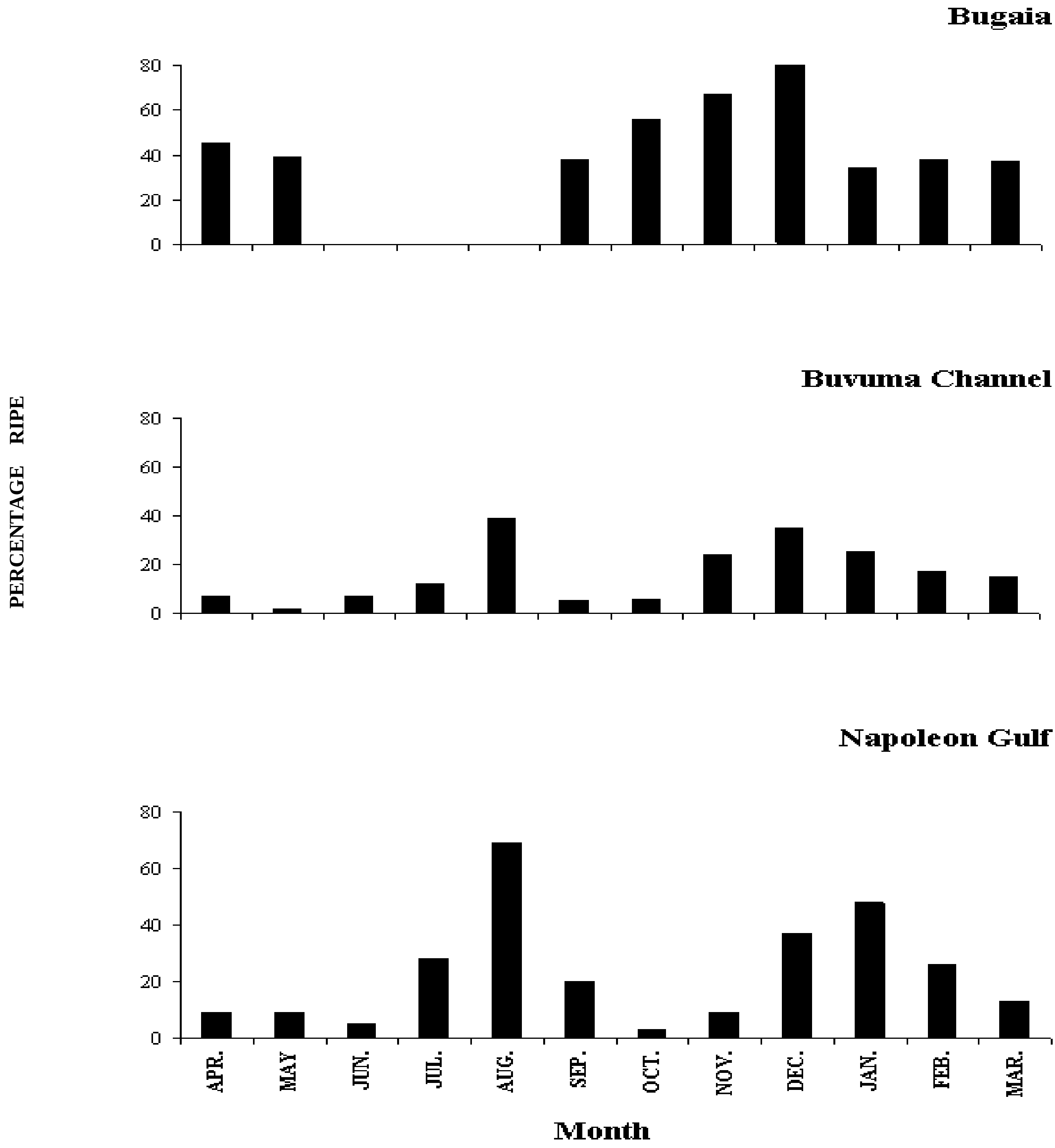

Figure 6. Percentage of ripe gonads in *R. argentea* – all sites

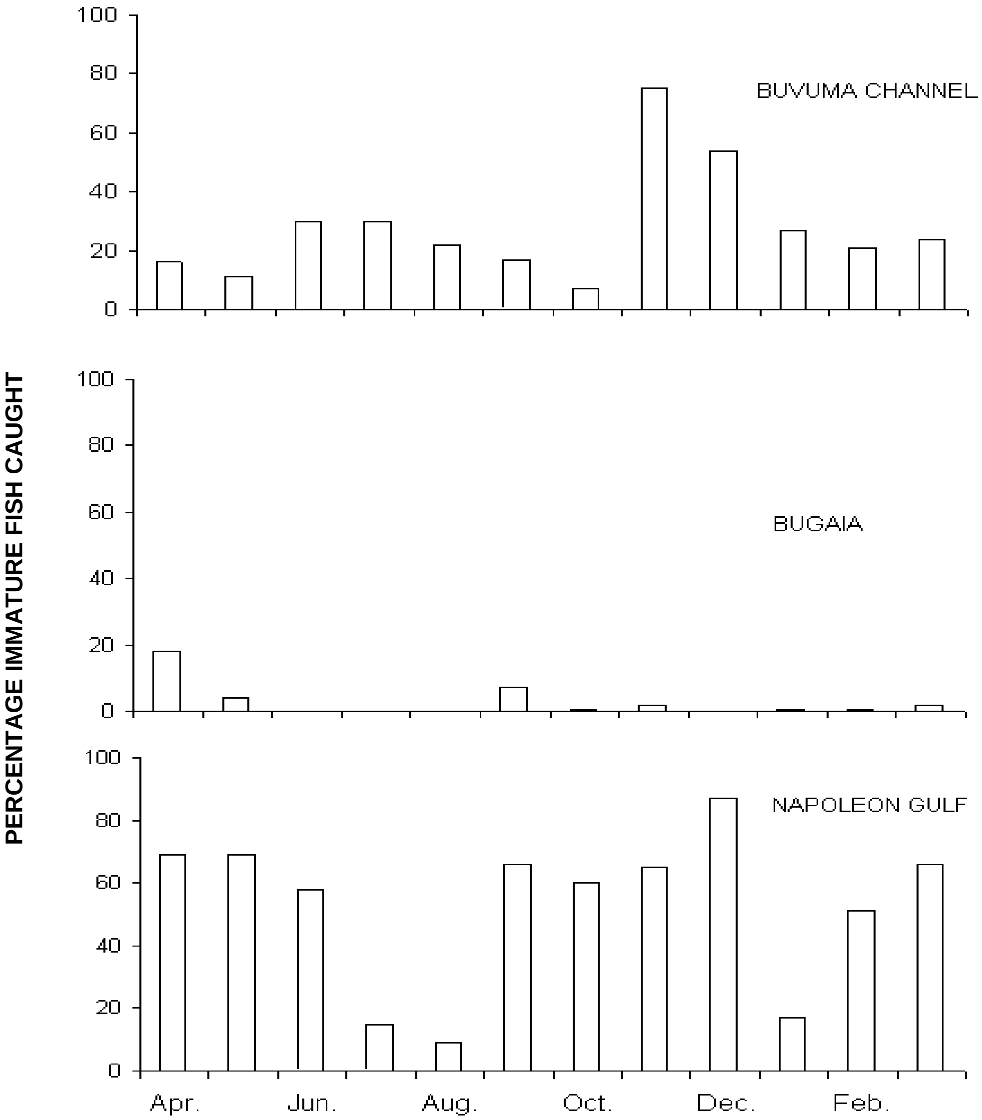

Figure 7. Monthly percentage of immature *R. argentea* caught by artisanal fishermen in Napoleon Gulf, Buvuma channel and Bugaia

Discussion

During the pre-perch period, *Rastrineobola argentea* grew to a large adult size with a mean length of 60 mm SL. This size was reduced to 48 mm SL in 1989 (Wandera and Wanink, 1995) and by 1998 had shrunk to 44 mm. Over the same period growth parameters of the species have also changed. In 1988 the asymptotic length was calculated as 64.5 with a growth constant (K) of 0.92 yr^{-1} (Wandera and Wanink *Op. cit.*). This had by 1992 changed to 54.0 with a K of 1.76 yr^{-1} (Wandera, 1999). The combined effect of predation by the Nile perch and human exploitation could be responsible for the changes in growth parameters above and size at first maturity (Fig. 3). *Rastrineobola argentea* is exploited by light attraction (Okedi, 1981; Witte and van Densen, 1995). Fishing gears used in the capture of mukene in Ugandan waters are scoop nets, beach seines and lampara (boat seine) nets. Initially, the beach seine nets in use were of a stretched mesh size of 10 mm. With the introduction of the lampara boat seine net, the mesh size was reduced to 5 mm. Size structure of mukene caught by fishermen from the study area (Figure 5) indicate that the lampara (boat seine) nets operated away from closed bays and off the shore does not harm the fishery by capturing many immature fishes.

Management strategies suggested for the mukene fishery of Lake Victoria

Rational exploitation of *Rastrineobola argentea* in Lake Victoria can be maintained if strict management measures are put in place. The most vital intervention points have been identified as:

(a) Establishment of closed fishing grounds

Many fish species, especially their juveniles occur in sheltered bays and very close to the shore. Because of the high numbers of immature mukene caught in Napoleon Gulf and other similarly sheltered bays (Figures 5 and 7), such grounds should be closed to mukene fishing. Mukene catches from fishing grounds further out in the open lake contain fewer immature individuals. Open waters as those in Bugaia are the best grounds for mukene fishing.

(b) Establishment of closed fishing seasons

Recruitment periods, when high numbers of juvenile mukene occur should be closed to fishing. While sheltered bays have high numbers of juveniles the whole year round and are recommended closed grounds, "Island" zones such as Lingira experience high recruitment only from November to December (Fig 7). The two months could be declared closed to mukene fishing. Closed seasons are however not necessary in the open waters.

(c) Control of fishing methods and gears

Beach seines capture many bye-catch fish species. Juveniles of non-target species occur very close to the shore and tend to be dragged along during beach seining. Beach seines should therefore be discouraged. The lampara (boat seine) is a better gear since it can be operated away from these shore dwelling fishes.

(d) Control of mesh size

Based on data collected in 1988, a 10 mm mesh net had been recommended as ideal for mukene exploitation (Ogutu-Ohwayo, Wandera & Kamanyi, 1998). With changes in the population structure of *R. argentea*, this mesh size is no longer appropriate. The present mean size of the mukene at 44 mm SL is small compared to 48 mm SL in 1988. Most fish would now not be retained in the 10 mm mesh net making it unprofitable for the fishermen. With the reduction in the size at first maturity, the mean percentage of mature mukene retained by a 5mm mesh net is now increased. Catches by this mesh size from recommended fishing grounds i.e. open water - Bugaia, and "islands" zone – Lingira contained low percentages of immature mukene (Figure 5). As long as nursery grounds for mukene are avoided the 5 mm mesh net is recommended for exploitation of the species. Meshes smaller than 5 mm should however be discouraged as they are likely to increase toll on immature mukene to unacceptable levels.

Conclusion

The study showed a gradual decline in the size of mukene caught from Lake Victoria between the pre-perch days and the present. Other biological parameters have also changed over this period. The recommended mesh size of 10 mm for the capture of mukene is no longer appropriate and 5 mm is suggested instead. Fishing very close to the shores and in sheltered bays captures high percentages of juvenile mukene and other species and is therefore discouraged. Fishing should, therefore, be restricted to the more exposed waters away in the "islands" zone and beyond.

Acknowledgements

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Potential strategies to address fishers problems in Lake Victoria, Tanzania

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Abstract

Local fishing communities riparian to Lake Victoria in Tanzania have since time immemorial exploited and highly depended on the fisheries of the lake. However their living conditions have been deteriorating despite an increase in the income generated from this fishery. Although there are a few successful fishermen, on average most of them cannot make their ends meet. Living conditions within the riparian communities are poor due to lack of sufficient sanitary, health and education facilities, and there is a very high incidence of diseases, illiteracy and poverty. Since the fishery of the lake turned commercial in 1980's due to the boom of Nile perch *Lates niloticus*, one expects the living conditions of these fishers and indeed the riparian communities to be changing. However, the reverse is what is being observed, WHY? This has been the concern of several people and of the ongoing Lake Victoria Environmental Management Project (LVEMP). As a way of partially addressing this issue, a survey was carried out in these fishing communities between January and March 2001 in the three regions bordering the lake on the Tanzanian side. The survey was undertaken to understand how fishers' conceptualize their conditions and for them to suggest strategies to address this condition. Participatory Research Tools were employed to solicit fisher's problems from their point of view as well as solutions to the identified problems. This paper presents and discusses the results of the survey and argues that among the various strategies proposed for improving fishers conditions, formation of fishers organizations seems to be paramount. This would be the starting point for solving the numerous problems identified.

Introduction

Lake Victoria is the second largest fresh water lake in the world, with a surface area of about 68,800km^2 . The Lake is shared by the East African countries, proportionally a large share is occupied by Tanzania (51%); Uganda (43%); while Kenya owns the smallest (6%). Besides these natural features, the lake has much socio- economic importance to these three countries. For instance, it contributes a gross economic product of about US$ 3-4 billion annually (GEF 1996, RoK, RU and URT, 1995). It supports approximately 27 million people with incomes ranging between US $ 90- 270 per capita per annum. In addition to generating income, the lake provides employment to local fishermen/women (180,000) along the offshore. Others cultivate various agricultural crops and use the lakes waters for irrigation. Moreover, the lake provides marine transport within these three countries (Tanzania, Kenya and Uganda). Among the various activities going on in the lake, fishing is the leading activity (Greboval and Mannini 1992).

Fishing is dominated by three species namely Nile perch (*Lates niloticus)*, (Mkumbo, 1999) Dagaa (*Rastrineobola argentea)*, and Tilapia (*Oreochromis niloticus)* (Nsinda and Mrosso, 1999). Nile perch was introduced in the lake in 1950's. This introduction resulted in a boom of this species in mid 1980's. Since 1989 the annual production remained at a level which the local market could not absorb. In particular, it was difficult to sell the perch in the local market (Abila and Jansen, 1997). There was however a rapid increase in demand for Nile perch, which expanded beyond the three countries sharing the lake as a result of new markets in industrialized countries, especially the European Union. In order to satisfy this market, a number of fillet processing plants were established (Abila and Jansen, 1997). For example, there was a rise of the annual catch from the lake from 146,000 tones in 1988 to 231,600 tones in 1990 (LVFO Secretariat, 1999). These industries increased the benefits, which were being derived from this water body by the local fishermen.

It has been estimated that during the 1980's an additional 180,000 jobs were created in the primary and secondary fields of the fisheries industry. Many people who had been employed or under employed were able to obtain incomes at levels they had never experienced before. No wonder that many fisherfolk nicknamed the Nile perch the saviour.

Besides these changes, there are negative impacts associated with them. These include

i. Food insecurity: the increase of Nile perch demand by the fillet processing plants increased the price of Nile perch (to about 500-600/= Tshs per kilo)[1] making it less affordable by the local communities (Bokea and Ikiara, 2000; Abila and Jansen, 1997; Jansen, 1997).
ii. Dramatic change in the composition of fish biomass in the lake

In addition to changes in fish biomass, the lake ecosystem experienced a drastic change too. These changes brought about a number of interventions that gave birth of Lake Victoria Environmental Management Project (LVEMP) (GEF 1996, RoK, RU and URT, 1995). This project aims at; Maximizing the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and incomes, supply safe water, and sustain a disease free environment; Conserve biodiversity and genetic resources for the benefit of the riparian and global communities; and Harmonize national and regional management programs in order to achieve the maximum extent possible the reversal of environmental degradation.

Although the volume of fishes from the lake increased in 1980's, the welfare of communities involved in the fishing industry has been declining and in some cases at an alarming downward trend. This caused a lot of fear for the Tanzanian government. In fact majority of local fishers have remained poor due to lack of capability to efficiently participate in the industry. As a consequence, benefits and rewards accruing to the local fishers have not matched the increases in the fish production and therefore affected their welfare. To be able to improve their welfare, a lot of efforts are needed. Among them should be to design or come up with a well-designed strategy/strategies that will allow the local communities to improve their benefits and rewards.

As part of a wider effort in addressing this issue a survey was carried out throughout the lake zone in Tanzania. This survey sought fishers' views regarding problems they face, the causes of these problems and their possible solutions. This survey followed a previous survey which focused on determining factors which influence community participation in the industry. This was thought important due to the fact that all this information would enable strategizing on how

[1] USD 1 = T.shs. 870. This was the exchange rate at the time of the survey.

to improve benefits and rewards accruing to them. This current paper discusses the views expressed by the fishers.

Methodology
The survey employed Participatory Research Appraisal (PRA) tools (IIRR 1998) such as problem ranking and problem webs. The survey was carried out in some selected beaches of Lake Victoria in Tanzania. Discussions with fishermen, traders and local processors handling different fish species were undertaken.

Sampling
Two beaches were sampled in each of the three riparian regions (Mara, Mwanza and Kagera) based on the following factors:

i. *Permanency* – a beach qualified to be selected if it is used throughout the year.
ii. *Identified landing beach* - Beaches that have been identified by The Fisheries Department as the official landing beaches (these will be gazetted).
iii. *Beach which lands commercial species*. Beaches were considered on the fact that one or all of the three commercial species (Nile perch, Tilapia and Dagaa) are landed.

Based on these factors, several beaches were listed and from this list six were randomly selected. However, due to logistical difficulties experienced in the field only one beach was studied in Kagera region. Thus the beaches selected were Busurwa, Guta, Mwabulugu, Kabangaja and Igabiro[2].

Respondents
Three categories of respondents/groups were identified for the study:

i. (i). *Fishermen* - any person who was found in the beach who goes to the lake to get fish out of the water, whether he owns and or he doesn't own boats and or fishing nets.
ii. *Fish Processors* – Any person who was found in the beach he/she buys fish from fishermen to smoke, sundry, salt or deep-fry.
iii. *Fish traders* – Any person found in the beach who buys fresh and or locally processed fish to sell in that beach or elsewhere.

The PRA techniques

Problem ranking
This tool enables a community to identify and rank problems in order of priority by assessing their relative importance using a set of criteria. By using this technique, the community is enabled to focus their energies and resources to the most important problems. In using this technique, the community members gathered under a tree or in a room and they were asked to list all the problems they face in their area. This was written on the ground in a matrix form by

[2] Actually Kagera beaches share a lot of characteristics as was revealed in the first study preceding this one. For instance there are individual fishermen who controls these beaches. They own over 50% of the boats in these beaches, and other fishermen who are not part of their fleet must sell to him in order to survive in that beach

use of a stick by one of them. We then asked them to use leaves or sticks or stones to show the extent or scope (the number of people who are affected by the problem), the degree of impact (severity) of the problem and occurrence or regularity (frequency of occurrence). Each of these problems was assessed based on these issues (extent, degree of impact and occurrence) and a score between 1 – 5 was used for each issue. This exercise was summarized in a matrix form. The scores were added and the problem which had the highest score was considered as the major and a priority problem.

Problem Web

After identifying the major problem for each category, their causes were sought by use of problem webs. Problem web is a diagrammatic presentation of a problem, its causes and effects. It helps the community to determine the root cause and effects of the problems identified.

During this survey the problem which was identified as the major one was written down by one of the community members. We then asked them to indicate what caused the problem, the causes were written on the ground closer to the problem. The question "why?" was asked and answers written until a root cause was arrived at. An arrow was drawn from the root cause to the problem connecting all the intermediary causes. This was repeated until all possible causes were exhausted. In cases where root causes were the same, they were connected with a two-way arrow on the diagram.

Brainstorming

When the problems and their root causes were identified the community were guided through brainstorming sessions in designing strategies to address the problem. This technique helps to generate new information, perspectives and ideas or gather different opinions from several people on a certain topic in a short time. During the survey a selected group of the sampled respondents were brought together, we explained the objective and mechanics of the session. Each person was asked for their ideas relating to the topic each of the ideas was written down, sorted, classified and synthesized and an agreement was reached on a strategy to use in addressing the problem.

Besides these tools, Semi structured questions and Focus group discussions were also used to complement the three techniques above.

Results and discussion

This section presents the results for three categories interviewed. These are fishermen, traders and local processors. The survey was carried out between January and March 2001 in five beaches around the Lake beaches in Tanzania as shown in table 1.

Table 1: Basic Characteristics of the beaches studied

BEACH	REGION	DISTRICT	TYPE OF FISH LANDED	NUMBER OF BOATS¤	NUMBER OF FISHERMEN¤.
Busurwa	Mara	Bunda	NP, D, T	95	301
Guta	Mara	Tarime	NP, T	90	299
Mwabulugu	Mwanza	Magu	NP	50	120
Kabangaja	Mwanza	Mwanza	D	70	200
Igabiro	Kagera	Bukoba	NP, T	130	350

NP – Nile perch
T - Tilapia
D - Dagaa
¤ Data based on estimation by those interviewed on the day of survey

Problems Perceived by the Fishermen, Their Causes and Strategies to Solve Them

The prioritized problems (Table 2) for the fishermen in each of the beaches surveyed are discussed below. While the table presents problems ranked 1 to 6, in this paper discussion focussing on problems ranked as number one.

Inadequate education

Generally many fishermen lack secondary education, a high percent of these fishermen are primary school leavers. This is also reported by SEDAWOG[3] (2000) and Onyango (1999). There is inadequate education in fishing and environmental education, which has led to the problems related to low awareness in fishing activities. This lack of education is evidenced by the fact that fishermen normally lack vision in their fishing activities. To them getting fish is more important. Fishermen also lack education about marketing their products.

Table 2: Problems of the fishermen as they were being ranked when the discussion were conducted

PROBLEM RANK	NAME OF BEACHES				
	BUSURWA	**GUTA**	**MWABULUGU**	**KABANGAJA**	**IGABIRO**
1	Inadequate education	• Dishonest Agents • Lack of cooperation • Lack of education	Theft of fishing gears	• Poor Gears • Poor Environment • Market Instability	• Market Instability • Inadequate health facilities • Low Price • Employers harassment
2	Low fish catch	Poor gears	Market instability	Inadequate capital	Gears too expensive
3	Gears too expensive	Gears too expensive	High taxes resulting from privatizing	-	Theft

[3] This is an acronym used to refer to Socio-economic data working group of the Lake Victoria Fisheries Research Project. LVFRP is a fisheries research project (majorly stock assessment) funded by the European Union (EU)). This project ends in November 2001.

			the beaches		
4	Theft	Theft	Gears too expensive	-	Impact of water currents on fishing gears
5	Market instability	-	Inadequate capital	-	-
6	Change of weather	-		-	-

Causes

Belief: Fishermen believe that fishing activities do not require formal education. In fact in some societies (Urk in Netherlands), fishermen have made fishing a way of life. These fishermen have inherited fishing equipment from their parents, they are also making their children grow with this understanding. In the Lake Victoria, some fishermen's life begins and ends in fishing, without fishing life is not complete[4].

Inadequate extension services: In Tanzania the law enforcers who are District Fisheries Officers or other staff from the Fisheries Division are supposed to offer extension services. The extension services are quite inadequate due to the fact that these officers are few comperaed to the volume of work in all the districts within the riparian regions. The other problem is caused by the fact that the same officers are supposed to be law enforcers. Philosophically it becomes very difficult for one person to play two contrasting roles of extension service provider and law enforcer.

Polygamy: Some of the fishermen marry more than one wife, and a wife must at least have one or two children, as a result they cannot manage to send them to school because of fees.

Inadquate number of fishing colleges:– There are only three colleges in Tanzania[5]. These are inadequate to offer the much needed fishery education especially vocational training which is probably more needed by the majority of fishermen. In addition to this, these colleges do not have regular programs, which target fishermen. The focus of the running programs is directed to the department of fisheries and the processing sector.

Strategies

i. There is need to establish an independent, effective and efficient extension service. Extension service should be made autonomous from the Fisheries Department. It is proposed that an extension unit be created as an independent directorate under the Ministry of Natural Resources and Tourism, it should cater for fisheries, game and wildlife and forestry requirements under the ministry. This unit should operate from the central government.

ii. Fishing colleges should open their doors to fishermen, they should design tailor made courses to target fishermen, fish traders as well as local fish processors. In addition, these

[4] Personal observations made during a visit to Urk in Netherlands in 2000 and experience gained while working in the fisheries of Lake Victoria Tanzania.

[5] These colleges are; Nyegezi Fresh Water Fisheries College, Kunduchi and Mbegani Fisheries Colleges.

colleges should introduce mobile education services so as to be able to reach a wider population of the fishers.

Dishonest agents

The processing plants have introduced go-betweens, between fishermen and the plants who are known as agents. These agents are not trustworthy, they always hide vital market information such as the prevailing factory prices and the quantity required. This enables them to offer very low prices to the fishermen, in many cases half or less than half of the prices offered by factories (Owino 1997).

Agents also cheat the fishermen through weighing scales, these scales are faulty and fishermen loose between 15-25% weight for each kilo of fish. Sometime, agents take fish from fishermen on credit for several days, and records are written on exercise books. No copies are left with the fishermen for future reference. In case the exercise book is lost, the agent will pay according to what he remembers. The other problem is that there is no formal contract between fishermen and the agent. Thus, the agents can rarely be sued for a breach of contract. Fishermen on the other hand have no opportunity of legal address in the case of disputes.

Causes

The relevant government authority do not periodically check the weighing scales, in addition, there is lack of knowledge on legal actions fishermen can take once they identify a faulty scale.

Greediness: The agents are so greedy to quickly accumulate income without considering the impact of their activities.

Lack of cooperation: There is apparent lack of cooperation between fishermen as such they cannot protest against low prices offered by agents.

Strategies

i. A system should be set to regularly check all weighing scales by the relevant government authority, as is done for weighing scales used in shops and other businesses.

ii. Fisheries managers should be responsible to take legal actions against all agents using faulty weighing scales.

iii. Fishermen should form co-operative union. This union will among other things help in selling fish to the processing plants. When this is done then, the faulty weighing scales will be eradicated.

Lack of cooperation

Many fishermen operating in Lake Victoria Lake Victoria particularly in Tanzanian act individually and or independently. This is so because fishing in the lake historically or basically was for subsistence although occasionally it would be bartered with agricultural goods (Owino, 1999) and subsistence fishing did not require formal group activity. The transformation of the fishery to commercial state (Namisi, 2000) did not change the perception of the fishers from operating individually to groups. Individual fishermen with the ability to acquire fishing equipment resorted to employing crewmembers who do the actual fishing. These crewmembers do not cooperate. Due to differences in incomes, cooperation was not seen as important in fishing activities especially by the fishers until theft of gears and frequent deaths[6] of fishermen had occurred.

Causes

i. There is low awareness on the benefits of the co-operation and how to legalize the groups.

ii. Self-confidences on individual performance. Fishermen console themselves with the fact that given the conditions under which they operate, they are not likely to do any better. Thus they have developed some sort of confidence in their performance level. This condition proves the idea of poor extension service mentioned above offered to these fishermen. Such services could have opened their minds to appreciate their abilities and various opportunities of cooperating in order to improve their status.

iii. Stereotype views about the earlier co-operative societies, for example agricultural co-operative societies that collapsed because of poor fund management, dishonest officials, and formation of groups without firm foundation. As a result fishermen have negative attitudes towards co-operative societies.

Strategies

i. Fishermen proposed that extension services should be strengthened.

ii. Fishermen proposed that they should be compelled to form association/ co-operatives by an act of the minister concerned. The minister should enact a law that compels all fishermen in the lake belong to an association. Such associations and or co-operatives should comprise fishermen and not non-fishermen.

iii. Organizations have created good results especially in improving fisher's status. Practical examples include fishing cooperatives in Japan, Producers Organizations in Netherlands and United Kingdom (Langstraat, 1999; Phillipson, 1999). Indeed besides addressing fishers benefits, organizations embedded on the collective action theory (Ostrom, 1990) enhances management of the resource. In Finland the Fisheries Act of 1982 recognized the importance of fishers organizations both socially and economically and thus introduced fisheries region (these are organizations that allows for the cooperation of all persons and groups interested and involved in fisheries management). This was an improvement of the original voluntary groups which were later made compulsory by law

[6] Frequent deaths were experienced as a result of the lucrative fishing which attracted people who had no experience even in swimming. The beach residents came together and set up by-laws. One such by-law which is similar in almost all beaches across the Tanzanian side is that, if a fisherman dies in the lake, all fishermen would not go fishing until the dead were found. This was a starting point for cooperation.

for all fishermen (Sipponen 1999). Such cooperation is very crucial for co-managing Lake Victoria (Geheb and Crean, 2000; Onyango 2001b)

Theft/robbery

There is rampant theft and robbery of gears and engines in the lake. The problem affects both, fishermen and their crews. Once their gears have been stolen, they have to start afresh and this hinders their development. Other effects include risk in loosing their lives, this is because some are killed when robbers attack in the lake or they loose some parts of their body. Gear theft has also been noted as a problem affecting fishermen (Geheb and Crean, 2000)

Causes

Harassment of some fishermen who have modern gears. Some crewmembers claimed that they are forced by their employers to steal other's gears once their employers' gears have been stolen.

Jealousy between fishermen because of the gains from fishing. Some fishermen steal others' gears in order to stop them or to make them unable to make gains.

Strategies

Fishermen agreed to initiate cooperative union, and each member contribute some money to purchase engine for surveillance. Through their union they would ensure security of their nets and engines.

Market instability

Market is a very important tool through which to allocate resources in the most efficient way. It can however be used to misallocate resources especially when forces of demand and supply are not allowed to operate freely as required. This is what is currently being experienced in the Nile perch fisheries of Lake Victoria (Gibbon, 1999). The market problem to fishermen is two fold in Lake Victoria; low prices of fish and market in-availability.

Low Prices of fish

FAO (1996) noted that prices are marginally influenced by local circumstances and depend more on the conditions imposed by international markets. However for Lake Victoria Nile perch, there is a high price elasticity of demand when Nile perch production is mainly for local consumption (Greboval 1989). At significantly high levels of production, however, Nile perch price tends to rise and be more stable because of the geographic expansion of the market. There is also evidence on the issue that the value of the dollar as well as frequent bans on fish exports have had impacts on fish prices. However to a large extent local fish prices have been set by fish filleting factories (Namisi 2000). This makes all fishermen to be price takers and these prices set at the factories are by themselves very low for instance they range between Tshs. 750-1500 (i.e. USD 0.9 – 1.7) (I USD = Tshs. 870). This is the price that the filleting plants buy the fish. The agents who buy the fish from the fishermen reduce this further to more than half claiming that the difference meets transport costs. In some beaches, there is an arrangement where fish landed by crewmembers are bought by fish collectors, these fish collectors then transport the fish to a second category of collectors who work on behalf of the agents. These second collectors have a direct link with the agents. This arrangement makes fish prices to be very low especially to the crewmembers who work all through the night. This is so because at each level of sales, the person involved desires to make a profit.

Causes

Lack of competition: In some beaches like those in the western part and some Islands of the lake, a certain system has erupted where some fishermen monopolize fishing in a beach. They operate over 50% boats in that beach. In addition to this, they have the means to transport their fish to the processing plants in Mwanza. This implies that other fishermen in the beach must adhere to their terms and conditions if they want their fish to be bought. The consequence of this is that the monopolists buy the fish from other fishermen at very low prices. It has actually been discovered that processing plants undertake their fishing through such a system.

Dishonest Agents: Agents always hide information about prices to fishermen, because there is a big communication gap between fishermen and processing plants. They always take advantage of this gap by lowering the prices of fish. Usually they buy fish at a very low price almost half or less than half of the price offered at the filleting plants.

Involvement of processing plants in fishing: The involvement of processing plants in fishing narrows the fish market of local fishermen. The processing plants fulfills their demand for fish by involving in direct fishing, if their fishing efforts cannot provide enough raw materials then they buy the difference at very low prices usually Tshs 250- 500/= per kilo of fish.

Strategies

i. Fishermen agreed to initiate a co-operative union in order to strengthen their economic position and be able to participate in price determination. With such a union they can build up their position and start fish filleting so as to be able to compete effectively with the current filleting plants. They however proposed that education about co-operative union should be provided to them. Again this calls for extension service.

ii. Fishermen suggested that the government should set minimum prices of fish product per kilo as it always does for agricultural products. Although fishermen would want to see government involvement in the market, this is not in line with the conventional economic theory which argues that markets allocate resources most efficiently when there is least government interference. However this is an indication of their inability to effectly participate in the industry.

iii. Fisheries management should select only few beaches for landing in order to control the price difference. From this proposal it appears that fishermen are not fully informed of the efforts the Fisheries Division are making towards gazzeting official landing beaches which have already been identified. Again the need for extension service.

iv. Processing plants should advertise their buying price of fish per kilo in mass media radio, Television and Magazines just like it is done for agricultural products.

Market in-availability
The market problem is serious in some beaches. There are no agents or factory representatives in those beaches to buy the fish from the fishermen, as a result the fishermen sell their fish to the nieghbouring countries (smuggling) like Kenya and Uganda. When the authorities enforce the laws then these fishermen lack market for disposing their fish. The result of this is that the fish is either given away to villagers at very low prices or given free to relatives in order to avoid spoilage.

Causes
Long distance: As many processing plants are located in Mwanza region, it becomes difficult for some fishermen to reach them. The road conditions (most of the roads leading to the beaches are murram roads) are impassable during rainy season. The effect of this is that some processing plants are not ready to incur high transport costs for collecting fish from far beaches. This therefore makes fish landed at such beaches to sell at very low prices.

Strategy
Infrastructure especially roads to these areas should be improved.

Inadequate health facilities
Fishermen claimed that this is a very serious problem to them, and that a large part of their incomes are spent on medical services. This inadequacy has also led to diseases such as bilharzia, diarrhea, headache, and sexually transmitted diseases (STD) (Onyango 2000a). Fishermen are affected with STD's because they don't use condoms.

Causes
Lack of dispensaries or hospitals and or clinics within the beaches. Actually in all the beaches visited only one beach was four kilometers a way from a government dispensary. Others were either void of any medical facility or un-properly stocked drug shops.

There are inadequate medicines in chemist shops that make such medicines to be very expensive to be afforded by fishermen.

Strategy
In some beaches, fishermen agreed to initiate a union through which they would construct dispensaries around their beaches.

Employer harassment
The problem seemed to be serious in some beaches, and issues that are considered by crewmembers as harassment are: lack of time to rest, fishermen allowed to get only reject fish for consumption and sometime are even forced to buy them, fishermen can be suspended without

any reason and or notice, they do not have sick leave. Given the fact that they are paid on a daily basis, if one falls sick and doesn't go to work, then he would not get paid for that day.

Causes
Employers are money driven and do not consider any social and or health issues of their employees.

Strategies

i. Laws must be formulated and implemented to protect the crewmembers.
ii. There must be an open contract that will identify all responsibilities and rights of the crewmembers.

iii. Problems their perceived causes and strategies for traders

The prioritized problems for the traders (Table 3) are discussed below.

Table 3: Problems of traders

PROBLEM	**NAME OF BEACHES**				
	BUSURWA	**GUTA**	**MWABULUGU**	**KABANGAJA**	**IGABIRO**
1	-	Poor Equipment	• High taxes • Inadequate Capital		Low Price
2	-	Inadequate Capital	• High transport costs • Lack of Education		• High transport costs • Poor Equipment
3	-	• Low prices • Poor roads	Low fish supply		Inadequate capital
4	-	Faulty weighing scales	Poor Equipment e.g. containers, wheel barrows, etc		Market instability
5	-	• High taxes • Restrictive regulation and rules	Low price		

Poor equipment
Traders need storage equipment in order to keep their fish in a better condition which would be preferred by their customers. Some of these traders have to travel long distances to sell their fish to local markets, many of them use bicycles to transport the fish to these markets. Due to the fact that they lack good storage equipment and in addition to poor transport facilities, they are forced to sell their fish at low prices in order to avoid spoilage. This has also been noted by SEDAWOG (1999).

Causes
They have inadequate funds to purchase such equipments to support their activities. This leads to low profits and savings.

Strategies
Owners of the processing plants should assist such traders by providing various equipments on credit in turn to fish supply.
Government, NGO's, Banks and Financial Institutions should give financial support to traders at fair conditions.

Taxes
The problem affects majority of the traders. They claim that they pay double tax on the same product. When they buy fish at the beach, they pay a tax for each Kilo of fish they buy. When they go to the markets, they are also charged a tax at the market. This makes them operate their activities at marginal profits. For instance a trader is supposed to pay between Tshs. 6- 10 /= per kilogram (depending on the district) as a tax when he/ she buys, fish from fishermen again he/she is going to pay when she/he reaches the market place. This amount differs from one district to another as the district councils set them.

Causes
The only reason given was privatization of beaches. Since the beginning of this millennium, most district councils who have control over these beaches sought to improve incomes from these beaches, privatization was thought to be an efficient way to do this. Individuals of groups tendered to collect taxes from these beaches and deliver to the district councils. The result was that those who won the tenders have not honestly followed the regulations on amount to charge. In addition traders who used to evade taxes can now not evade paying.

Strategies
Tax payment should be reviewed in order to avoid double taxes. This has been considered under the Fish Levy trust study by the Fisheries Division (report forth coming).

Inadequate capital
Most traders operate with capital ranging from T.shs. 5,000 – 50,000. This makes them unable to purchase the basic equipment necessary for the trade SEDAWOG (1999) also noted this problem.

Causes

Poverty: *:* The initial investment capital which these traders invested was low hence minimal returns. Other causes include; poor means of transport such as use of bicycles compounded by poor roads, since they need to travel for a long time to the market place; for instance, in some cases the fish is transported for over 10km, thus by the time the fish reaches the market it is already bad.

Barter trade: In some areas the trade is barter. That is, when traders take their fish to the market, customers may not have money to purchase the fish, in turn they exchange their fish with other goods such as maize, cassava, beans, and the like; which are of less value compared to the fish they have.

Restrictive conditions for getting credits from financial institutions: Traders fail to get credits from financial institutions such as Banks because of too much restrictions and conditions, for instance, assets for securities like land, house, which some of them do not own and or if they own, they do not have the necessary documents to prove ownership.

The only available sources are the NGO's who provide credit and saving services. Even some district councils provide the loans but at very low levels. These do not increase their capital but only keeps them in the business.

Strategies

i. They suggested that credits should be given with fair conditions

ii. They all agreed to initiate a co-operative union. They however request for education on how to operate and control such union.

Problems their perceived causes and strategies for processors

Table 4: ***Problems of the local processors.***

PROBLEMS	NAME OF BEACHES				
	BUSURWA	GUTA	MWABULUGU	KABANGAJA	IGABIRO
1	Inadequate capital	Dangerous wild animals e.g. hippopotamus and crocodiles Corporation Health	Lack of corporation	-	Low fish supply
2	Low fish supply	Inadequate capital	Inadequate capital	-	Inadequate inputs
3	Market instability	Low fish supply	Low fish supply	-	Low purchasing power
4	-	-	Poor tools eg kilns Market instability	-	-
5	-	-	Inadequate skills and techniques in frying and smoking	-	-

Inadequate capital

This problem affects many local processors like smokers, salters, sun-driers, and fryers. These people lack enough funds and as a result they fail to buy enough fish for processing. This makes them to depend on rejects only for processing. In addition, they still use traditional kilns, which are made out of mud to process their fish.

Causes

Poverty is the major cause of this problem. They started their business with little capital hence poor returns too. This is compounded with a very big list of expenditure items.

Inadequate education: Most of the processors lack education on how to run their business. As a result they are not able to find different markets far from the beach in addition to increasing their profits. Due to inadequate education they are not competitive too.

Lack of information about capital sources: Most of the processors are not aware that there are different organization, which could help them to increase their capital such as banks, NGOs, government, etc

Strategies

Processors noted that the strategy to solving their problem is to corporate in order to bare cost of operations so as to improve their capital.

Processors also requested for elementary business education.

Dangerous wild animals

In some beaches like Guta this problem is very serious. These wild animals like hippopotamus and crocodiles kill people and some of the processors have lost part of their bodies.

Causes

i. Expansion of settlements makes these animals to lack enough space.

ii. Currently there is no Game Officer stationed at this place to check on such animals.

iii. Superstitious believes that these animals belong to some villagers.

Strategies

The concerned Ministry should provide them with a permanent Game Officer at the beach.

Cooperation

Generally many processors operate their processing activities independently. This lack of corporation has made them unable to increase their capital. As a result they have continued to operate their business with the capital ranging between 1,000/= to 10,000/=Tshs.

Causes

Low awareness on cooperation: they are not adequately informed and mobilized to form groups. They are aware that groups can help them, however they still do not know how to go about forming such groups.

Strategies

There is a need to have an effective and efficient extension services within the fishery division to handle this low awareness.

Processors unanimously agreed to initiate cooperative unions so as to solve their problems.

Health

This problem is too serious to all local processors; because majority of them are still use traditional kilns, which are made out of mud, and use firewood as source of energy, which affects their health. Major diseases which processors suffer are cough, headache, eye problems, and dizziness.

Causes

Lack of education on improved kilns: Local processors claimed that they lack education on how to use and build improved kilns

Inadequate capital: They are not able to buy improved equipments and inputs for their processing activities like improved kilns.

Lack of dispensaries: The absence of dispensaries in many beaches, cause local processors to lack health services and medical advice on how to take precautions when they are conducting their local processing activities.

Strategies

i. Government and NGOs should provide education on how to make and use the improved kilns.

ii. They all agreed to initiate a corporation of credits and servings so as to raise their capital

iii. Health sector should provide services frequently

Low fish supply

This is a problem which has also been noted by fishermen (SEDAWOG, 2000) and confirmed by biologists (Tweddle and Cowx, 2000). It is a major problem to the local processors, because it leads to lack of fish for processing. These local processors either have to compete with the processing plants or have to depend on fish rejected by these plants. They also have to compete with local consumers who buy the fish fresh. Due to this competition they get very low supply of fish. This means that they use very low capital at the time there is no supply of fish.

Causes

Climatic conditions: Changes in the weather leads to frequent fluctuations in the supply of fish.

Processing plants***:***The fishermen give first priority to processing plants. The rest is sold to local processors. The fish sold to local processors are the rejects or juveniles fish of low quality.

Illegal fishing methods***:*** Although there are rules, which stipulate fishing in what season and areas, the type of fishing gears acceptable and the type or size of fish, which can be caught, there are those who still use illegal fishing techniques. These techniques reduce or lead to a daily declining marginal low catches of fish and as a result processors lack fish for processing.

Strategies

Beach Management Units (BMUs) formed across the lake should make sure that all regulations are enforced.

CONCLUSIONS

The results from this survey point out several things, among them is that local fishers are not in control of their natural resources. This is not because they do not want but they have been pushed to this situation due to the economic situation in which they have found themselves. Many of them have generated benefits and rewards in terms of employment and income, equally some have been sidelined for instance local processors. Secondly, there is an uncoordinated fishers activities among themselves. The fishers are unorganized to the extent that exploiting them becomes very easy. In addition this has made it very difficult for them to participate effectively in controlling the market so as to generate higher profits. Due to this fact, agents have erupted and are over exploiting them by offering low prices. However it is worth noting that fishers are willing to cooperate and this is very important. Thirdly, extension service is inadequate. This has accelerated poor performance by the fisher and also hindered them from increasing their benefits and rewards. In order to reduce existence of these problems if we cannot solve them, there’s need to look at two major issues; extension service and organizing fishers into formal groups.

RECOMMENDATIONS

i. Establish a Directorate of Extension Unit under the Ministry of Natural Resources and Tourism

The role extension service can play in not only soliciting for support towards sustainably utilizing the lake resources has been underestimated. This has resulted into combining this role with a contrasting one of law enforcement. As already pointed out, extension is crucial in increasing benefits and rewards to the fishers. Namisi (2000) notes in his work that there's need to invest in information sharing and education of the local fishing communities. He further notes that education is very important for a society whose culture and life has directly depended on fish for many years.

Thus it is recommended that an independent extension unit should be established in Tanzania. This unit should be formed as a Directorate under the Ministry of Natural Resources and Tourism. It should cater for the ministries all departments and Institutions.

ii. Mobilize fishermen to form fisher's organizations

Formation of a fisher's organization in Lake Victoria is now an inevitable fact. Besides the advantage such an organization will generate for the fishers, the lake's resources is also bound to benefit. This is so because the already noted decline in fish resources has been caused by among other things human activities which includes use of illegal fishing techniques. Although this has been addressed through forming Beach Management Units across the lake, not all interest groups have been included in these units, moreover these units operate within the structure of the government (Onyango, 2001b), they are not autonomous to make independent decision and the benefits to be derived from these units are not immediate to the fishers, as such they may be less effectiveness as anticipated. In order to create effective system autonomy of the fishers is very necessary. .

It is therefore recommended that one, a law should be enacted to induce all fishermen in Lake Victoria to belong to an association. Secondly such an association should either be based on a district/regional level other than beach level. It would be very easy to deal with fishers groups than to deal with them individually. The suggestion here is that fishermen, traders and processors should each form an association. The three associations should combine to form an umbrella association either at the district and or regional level

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Zooplankton Communities Of Some Tanzanian Lake Victoria Basin Water Bodies

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Abstract
A survey of the zooplankton communities of some Tanzanian Lake Victoria Basin water bodies was conducted during September/October 2000 and March/April 2001. Plankton nets of mesh sizes 100 μm and 65 μm respectively were used to collect qualitative zooplankton samples from the water bodies on two occasions September/October 2000 and March/April 2001. The samples of zooplankton collected were made up to twenty taxa of rotifers and thirteen crustaceans. The most frequently encountered rotifers were *Asplanchna* spp., *Brachionus angularis, Brachionus caudatus, Brachionus calyciflorus, Brachionus patulus, Keratella cochlearis, Keratella tropica, Keratella quadrata, Lecane bulla*, and *Synchaeta* spp. The most common crustaceans were *Thermocyclops emini*, *Thermocyclops neglectus* and *Diaphanosoma excisum*. In terms of numerical abundance, Kyarano Dam contributed the highest density. In September/October 2000, when the mean total number was 179,689 m^{-2}. In March/April 2001 the highest density of 479,015 m^{-2} was observed in Lake Ikimba. The structure and composition trends of zooplankton in the surveyed water bodies may be related to both intensity of predation and limitation by environmental factors, which may include the nature of the water bodies, and food quality and quantity.

Key words: Satellite Lakes, Composition, Zooplankton, Diversity, abundance.

Introduction
The zooplankton community in many lakes plays a very important role in the lakes' trophic network as grazers of the rich phytoplankton and as nutrient recycling agents in the lake. When the zooplankton feeds on the phyto and pico-plankton they break down the algal and bacterial cell walls and thus through their feeding habits, defecation, and respiratory products, make available essential growth nutrients of algae (Mavuti and Litterick, 1991). The zooplankton availability is an important factor in determining relative survival of juvenile fishes (Fernando, 1994; Mavuti 1983). Also some species of zooplankton especially amongst the cladocerans and rotifers may be used as indicators of organic and chemical pollution (Mavuti and Litterick 1991). The broad and descriptive community ecology is essential and may demonstrate important species associations and succession, diversity and seasonality. These attributes are useful in elucidating functional mechanisms and ecological interaction of zooplankton and their environment.

Satellite lakes within Lake Victoria catchment area have been discovered to be refuges for the indigenous and endangered fish species of Lake Victora (Katunzi, 2001), some of which are zooplanktivorous fishes, *Haplochromis* spp. Despite the importance of these water bodies very little has been done on zooplankton ecology. Some of the existing information on zooplankton research in East Africa include that of Green (1967, 1971, and 1976) who studied the ecology distribution and production of zooplankton communities in five lakes in western Uganda, and Mavuti (1983; 1991) and Masai (2001 in press) who studied some satellite lakes in Kenya. Only one study of zooplankton ecology has been undertaken in some satellite lakes, a dam and a river within Lake Victoria basin in Tanzania (Waya, 2001).

In contrast to Uganda and Kenya very little is known about the zooplankton ecology in the Tanzania Lake Victoria Basin. A study was thus carried out to determine the pattern or structure of zooplankton community in selected satellite lakes, dams and river.

This paper reports the results of the study including zooplankton species composition, diversity and abundance in these chosen Tanzanian Lake Victoria basin water bodies.

Materials and methods

Study Sites

The study was conducted in Mara, Kagera and Mwanza regions. Zooplankton were collected in eight water bodies from twenty four sampling stations. In Mara region samples were collected at Mara River, Kyarano Dam, Kirumi flood plains and Kubigena Oxbow Lake (1° 36.271' S 34° 08.186' E), in Mwanza region at Malimbe (2° 37.471 S' 32° 53.867' E), in Kagera region at Lake Burigi (2^{o}.05.299'S 31^{0}17.353'E), Lake Katwe (1° 22.500'S, 30° 41.100'E) and Lake Ikimba (1° 27.204'S, 31° 35.208'E).

Methodology

Three stations were sampled from each site; two in the open waters and one taken under the microphytes at the littoral areas using a tube sampler. A plankton net of 100 μm having an opening of 22 cm was used in September/October 2000. In March/April 2001 a net of 65 μm mesh size having an opening of 29 cm was used. The net was lowered as close to the bottom as possible without disturbing the sediment and carefully hauled to allow the water to drip. The net was rigged with a weight to enhance vertical sinking. Three replicate samples were combined to make a composite sample. Fresh samples were preserved in 4% sugar formalin.

In the laboratory each sample was diluted, agitated and sub-sampled with a 5ml syringe. The zooplankton were counted in three sub-samples (two of 2 ml and one of 5 ml). The dominant animals were not counted in the second and third sub samples, when at least 100 animals had been counted. The sub-sample was placed on a modified counting chamber and examined under the microscope at x40 magnification. Taxonomic identification was done using identification keys developed by Ruttner-Kolisko (1974), Korinek, (1984), Boxshall and Braide (1991), Maas (1993) and Korovchinsky (1993), and the species diversity determined. Adult males and females were not separated but identified to species. The development stages of copepods stages one to five were lumped together as a single count category (copepodites). Nauplii stages were also grouped together. Density of zooplankton was computed as follows:

$D = N/V$ ………………………………………………………………………………..1

Where

N =Number of individual samples

= (Number in sub-sample x volume of sample)/sub sample volume

V = Volume of lake water filtered = $\pi r d^2$ where:

r = radius of the mouth of the net

d = depth of the water

Results

Species of zooplankton observed in September/October 2000 and March/April 2001 in the surveyed lakes are shown in table 1 & 2 and the zooplankton mean numerical abundance in the open and the littoral areas is shown in figure 1 & 2.

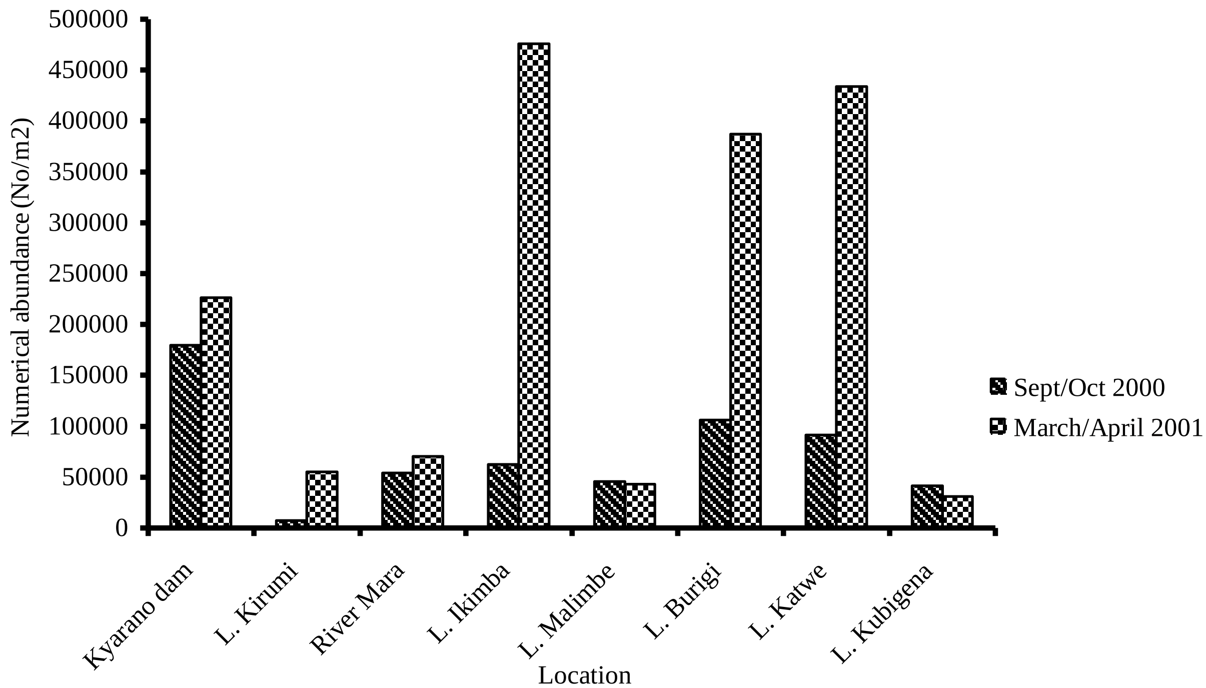

Fig. 1: Zooplankton numerical abundance in the open waters of the satellite lakes

During the period September/October 2000 eleven species were recorded from the samples collected from Kyarano Dam (Table 1). The mean total zooplankton abundance was 179,689 m^{-2}. In March/April 2001, seventeen species were encountered; rotifera contributed the largest number of species (8), followed by copepoda (6) and cladocera (3). The species observed were *Ceriodaphnia cornuta*, *Chydorid* spp., *Diaphanosoma excisum, Themocyclops incisus, Themocyclops emini, Themocyclops neglectus, Tropcyclops confinnis, Tropocyclops tenellus, Thermodiaptomus galeboides, Asplanchna* spp.; *B angularis, B. falcatus, F. opoliensis, K. cochlearis. K. tropica, Synchaeta* spp.,

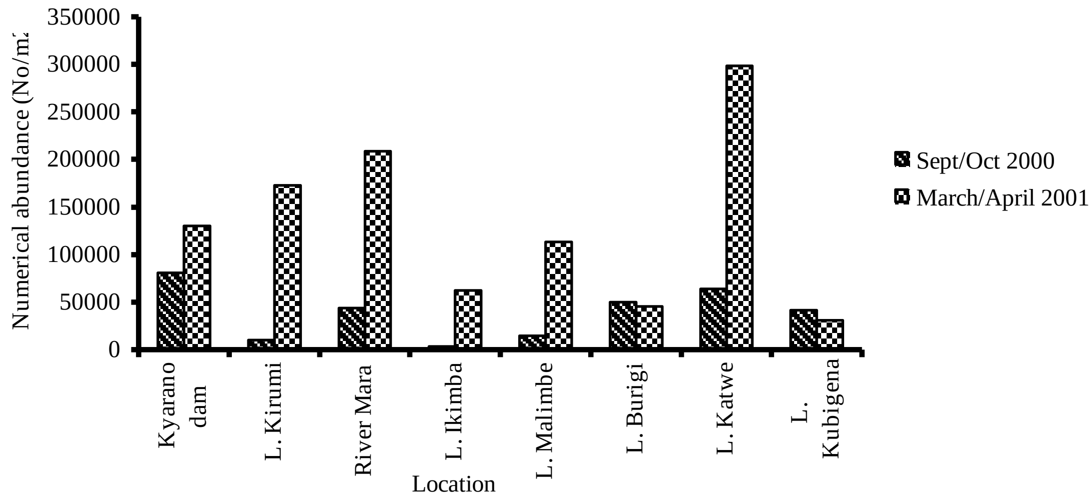

Fig. 2: Zooplankton numerical abundance in the littoral areas of the satellite lakes

and *Lecane bulla* (Table 2). Total zooplankton mean numerical abundance was 226,449 m^{-2}. The copedoda was the most dominant group accounting for 83% of total zooplankton abundance, followed by rotifera (11%) and cladocera (6%) (Table 2)

In Lake Kirumi a total of fifteen species were observed in September/October 2000 (Table 1) and twelve species were observed in March/April 2001 (Table 2). In both studies eight species of rotifera encountered were *Ascomorpha* spp., *Asplanchna* spp, *Brachionus angularis*, *Brachionus calyciflorus*, *Lecane bulla*, *Synchaeta* spp., *K. cochlearis* and *K. tropica.* Cladocera contributed six species, *Alona* spp., *Ceriodaphnia cornuta*, *Chydorid* spp., *Daphnia lumhortzi*, *Diaphanosoma excisum* and *Moina micrura.* Three species of cyclopoida were observed *T. emini*, *T. neglectus* and *T. tenellus*. Total zooplankton mean numerical abundance in September/October 2000 was 7,146 m^{-2}. The most important group in terms of numerical abundance was cyclopoida which contributed 39% followed by rotifera 31.8% and cladocera 29%. The mean temperature was 24.1 ^{o}C. In March/April 2001, total zooplankton mean numerical abundance was 54,996 m^{-2}. The cyclopoid were the most common group and contributed 55% of the total zooplankton mean numerical abundance, followed by rotifera (44%). Cladocera were absent in the sample collected at the open waters, but in the littoral area the cladocerans were very common accounting for 44% of the total zooplankton abundance followed by rotifera (39%) and cyclopoids (16%) (Table 1).

In River Mara fifteen species of zooplankton were observed in September/October 2000, Rotifera contributed six species, *Brachionus angularis*, *Brachionus calyciflorus*, *Branchionus caudatus*, *Brachionus falcatus*, *Synchaeta spp*, *Keratella tropica.* Copepoda five; Cyclopoida, four species *Thermocyclops emini*, *Thermocyclops neglectus*, *Tropocyclops confinnis*, *Tropocyclops tenellus* and Calanoida one, *Thermodiapomus galeboides* and Cladocera three species *Daphnia lumhortzi*, *Moina micrura* and

Diaphanosoma excisum (Table 1). In March/April 2001, sixteen species were observed among them ten were rotifera; *Ascomorpha* spp., *Asplanchna* spp., *B. angularis, B. caudatus, B. patulus, Euchlanis* spp., *L. Bulla, Synchaeta* spp., *F. opoliensis* and *Tricocerea* spp. Cladocera spp., *Diaphanosoma excisum* and *Moina micrura*. Only three species of Cyclopoida were observed. *T. emini T. neglectus* and *T. Confinnis* (Table 2). Total zooplankton mean numerical abundance was 53,965 m^{-2} in September/October 2000 and 70,187 m^{-2} in March/April 2001. In River Mara only rotifers were found in the samples collected by net (Table 2). More species of zooplankton were collected in the littoral area by the tube sampler and the total zooplankton mean numerical abundance was higher reaching up to 203,445 m^{-2} (Figure 2). The cyclopoids were very common and contributed 61% of the total zooplankton mean numerical abundance followed by cladocera (27%) and rotifers (12%).

Lake Katwe contributed the highest number of species compared to other lakes in both studies, sixteen species of zooplankton were identified in September/October 2000 and twenty species in March/April 2001. Twelve were rotifers and included *Asplanchna* spp. *B. angularis, B. caudatus, B. Calyciflorus, B. patulus, F. opoliensis, K. cochlearis. K. tropica, K. quadrata, Trichocera* spp., *L. bulla and Synchaceta* spp. Five cyclopoid copepods included *T. emini, T. incisus, T. confinnis, T. neglectus and T. tenellus*, and three cladocerans, *Ceriodaphnia cornuta, chydoridae* spp and *M. micrura*. Total zooplankton mean numerical abundance in September/October 2000 was 90,149 m^{-2} and in March/April 2001 was 434,047 m^{-2}. Cyclopoid copepod contributed 74% of the total zooplankton mean numerical abundance followed by rotifers (23%) and cladocera (3%) (Table 1). More rotifers were encounted in the littoral area with twelve species compared to eight species in the open waters.

In Lake Ikimba seven species were observed during September/October 2000 and seventeen species were encountered in March/April 2001. Rotifera contributed 10 species *Ascomorpha* spp, *Asplanchna* spp, *Brachionus angularis, Brachionus caudatus, Kellikotia* spp., *Keratella cochlearis, Keratella tropica, Keratella quadrata , Lecane bulla* and *Synchaeta* spp., copepod contributed five species: *Thermocyclops emini, Thermocyclops neglectus, Thermocyclops incisus, Tropocyclops confinnis* and *Tropocyclops tenellus.* Only one species of cladocera *Bosmina longirostris* was observed. Total zooplankton mean numerical abundance was 62,359 m^{-2} in September/October 2000 and 476,015 m^{-2} in March/April 2001. Cyclopoid copepod were the most common group and contributed 90% followed by rotifera (10%). No cladocera were observed in the open waters (Table 1). In the littoral area rotifera were the most abundant group accounting for 80% of total zooplankton mean numerical abundance followed by cyclopoid copepod 15% and cladocera (5%)

In Lake Malimbe rotifers showed a higher diversity than other species in September/October 2000. The species encountered were *Asplanchna* spp, *Brachionus angularis Brachionus caudatus, Euchlanis* spp., *Filinia opoliensis, Keratella cochlearis, Keratella tropica, Lecane bulla* and *Synchaeta* spp. Only one cyclopoid copepod was observed *T. emini*, and one species of cladocera *D. excisum*. A total number of eleven species were identified. Total zooplankton mean numerical abundance was 45,730 m^{-2}

and in March/April 2001 43,265 m^{-2}. The cyclopoid copepod (adult, copepodite and nauplius larvae) was the important group in terms of abundance as it contributed 51% of the total zooplankton mean numerical abundance followed by rotifers (49%). No cladocera were observed in the open waters, but in the littoral areas they contributed 9% of the total zooplankton mean numerical abundance.

In Lake Burigi a total of sixteen species of zooplankton were identified, eight rotifers, four cladocerans and nine copepods. The species encounterd were *Brachionus angularis, Brachionus caudatus, Brachionus calyciflorus, Filinia opoliensis, Keratella cochlearis, Keratella tropica, Keratella quadrata, Lecane bulla*, *Thermocyclops emini*, *Thermocyclops neglectus*, *Tropocyclops confinnis, Tropocyclops tenellus, C. cornuta, D. lumhortzi, M. micrura* and *D. exisum.* The numerical abundance of cyclopoid was greater (94%) than that of rotifers (5%) and cladocera (2%). Total zooplankton mean numerical abundance in March/April 2001 at the open waters was 386,823 m-^{2}. In the littoral area the rotifers were more abundant accounting for 52% of the total zooplankton mean abundance (Table 1). In September/October 2000 the total zooplankton mean abundance was106,122 m^{-2}.

In March/April 2001 eighteen species of zooplankton were found in Kubigena Oxbow lake, eleven of them were rotifers and included *Asplanchna* species, *B. angularis*, *B caudatus*, *B patulus, Euchlanis* species, *F. opoliensis, K. cochleans, B. tropica, L. bulla, Synchaeta* spp. and *Trichocerea* spp. The rotifers contributed notably to the zooplankton structure followed by cladocerans two species, *Bosmina longirostris, Daphnia lumhortzi, Diaphanosoma excisum* and *Moina micrura*. The cyclopoid copepods contributed three species, *T. emini*, *T. incisus* and *T. neglectus.* Total zooplankton mean numerical abundance in the littoral area was 31,108 m-^{2}. Rotifers were the most numerous accounting for 45% of the total zooplankton abundance followed by cyclopoid copepod (40%) and cladocera (15%) (Table 1). In September/October 2000 Kubigena Oxbow Lake was very shallow with a depth of 0.4m. A total of eleven species were recorded, the total zooplankton abundance being 44,444 m^{-2}.

3.1 Taxonomic Composition

Three major group of zooplankton were observed, copepoda, cladocera and rotifera. Overall twenty one general and thirty three species were identified, of which twenty species were contributed by rotifera. The species encountered were *Ascomorpha* spp, *Asplanchna* spp, *B. angularis, B. caudatus, B. calyciflorus, B. patulus, B. falcatus, B. leydig, B. patulus, Euchlanis* spp., *F. opoliensis, Kellicotia* spp., *K. cochleans, K. tropica, K. quadrata, L. bulla, L. inermas, Synchaeta* spp., *Trichocerca* spp, and *Wolga spinifera.* Copepoda contributed six species *Thermocyclops emini*, *Thermocyclops neglectus, Thermocyclops incisus, Tropocyclops confinnis* and *Tropocyclops tenellus* and one calanoida *Thermodiaptomus galeboides.* Cladocera contributed 7 species, *Alona* spp., *Bosmina longirostris, Ceriodaphnia cornuta, Cydorid* spp., *Daphnia lumhortzi, Diaphanosoma excisum* and *Moina micrura.*

Table 1: Species of zooplankton observed in the surveyed lakes, Sept/Oct. 2000

Taxa	Kyarano	Kirumi	R. Mara	Katwe	Ikimba	Malimbe	Burigi	Kubigena
Cladocera:								
Bosmina longirostris	–	–	–	–	–	+	–	
Ceriodaphnia cornuta	+	+	–	–	–	+	–	–
Chydorid spp.	–	+	–	–	–	+	–	–
Daphnia lumhortzi (helm.)	+	+	+	–	–	–	–	–
Diaphanosoma excisum	+	+	+	+	–	–	+	–
Moina micrura	–	+	+	+	–	–	–	+
Calanoida	–	–	–	–	–	–	–	+
Thermodiaptomus galeboides	+	–	+	–	–	–	–	–
Cyclopoida								–
Thermocyclops emini	+	+	+	+	+	+	+	
Thermocyclops incisus	–	–	–	+	+	–	+	+
Thermocyclops neglectus	+	+	+	+	+	+	+	+
Tropocyclops confinnis	+	–	+	–	+	+	+	+
Tropocyclops tenellus	+	+	+	+	+	+	+	–
Rotifera:								–
Ascomorpha sp.	–	–	–	+	–	–	+	+
Asplanchna spp.	–	+	+	+	–	+	–	+
Brachionus angularis	–	+	+	+	–	–	–	+
Brachionus calyciflorus	+	+	+	+	–	+	+	
Brachionus caudatus	–	+	+	+	–	+	–	+
Brachionus falcatus	+	–	+	–	–	–	–	
Brachionus forficula	–	–	–	–	–	–	–	
Brachionus patulus								+
Keratella cochlearis	–	+	–	–	–	–	–	–
Keratella tropica	+	+	+	+	–	–	–	
Lecane bulla	–	–	–	+	–	–	–	–
Polyarthra spp.	–	–	–	+	+	–	–	
Synchaeta spp.	–	+	–	–	–	–	–	+
Trichocerca cylindrica	–	–	–	+	+	+	–	–
Trichocerca spp.	–	–	+	+	–	–	–	+
No of species	**11**	**15**	**15**	**16**	**7**	**11**	**8**	**13**

Table 2: Species of zooplankton observed in the open waters of the surveyed lakes, March/April 2001

Taxa	Kyarano	Kirumi	R. Mara	Ikimba	Malimbe	Burigi	Katwe	Kubigena
Cladocera								

Allona spp	_	+	_	_	_	_	_	_
Bosmina longirostris	_	_	+	+	_	_	_	+
Ceriodaphnia cornuta	+	_	+	_	_	+	+	_
Chydorid spp.	+	+	_	_	_	_	+	_
Daphnia lumhortzi (helm.)	_	_	_	_	_	+	_	+
Diaphanosoma excisum	+	+	+	_	+	+	_	+
Moina micrura	_	+	+	_	_	+	+	+
Calanoida								
Thermodiaptomus galeboides	+	_	_	_	_	_	_	_
Thermocyclops emini	+	+	+	+	+	+	+	+
Thermocyclops incisus	_	_	_	+	_	_	+	+
Thermocyclops neglectus	+	_	_	+	_	+	+	+
Tropocyclops confinnis	+	_	+	+	_	+	+	_
Tropocyclops tenellus	+	_	_	+	_	+	+	_
Rotifera								
Ascomorpha sp.	_	+	+	+	_	_	_	
Asplanchna spp.	+	+	+	+	+	_	+	+
Brachionus angularis	+	+	+	+	+	+	+	+
Brachionus calyciflorus	_	+	_	_	+	+	+	_
Brachionus caudatus	_	_	+	+	+	+	+	+
Brachionus falcatus	+	_	_	_	_	_	_	_
Brachionus forficula								
Brachionus leydig					+			
Brachionus patulus	_	_	+	_	_	_	+	+
Euclanis sp	_	_	+	_	+	_	_	+
Filinia longiseta	_	_	_	_	_	_	_	_
Filinia opoliensis	+	_	+	_	+	+	+	+
Kellicotia spp.	_	_	_	+	+	_	_	_
Keratella cochlearis	+	_	_	+	+	+	+	+
Keratella tropica	+	+	_	+	+	+	+	+
Keratella quadrata	_	_	_	+	_	+	+	_
Lecane inermas	_	_	_	_	_	_	_	
Lecane bulla	+	+	+	+	+	+	+	+
Synchaeta spp.	+	+	+	+	+	_	+	_
Trichocerca cylindrica	_	_	_	_	_	_	_	+
Trichocerca spp.	_	_	+	_	_	_	+	+
Wolga spinifera	+	_	_	+	_	_	_	_
No of species	**17**	**12**	**16**	**17**	**14**	**16**	**20**	18

Discussion

The study of September/October 2000 show that the highest species diversity was observed in Lake Katwe where sixteen species were recorded. In this Lake, rotifers contributed ten species, the common ones being *Polyathra* spp, *Tricocerca cylindrical* and *Brachionus caudatus* which contributed 7%, 4% and 2% of the total abundance of zooplankton, respectively Cyclopoida contributed four species but was very important in terms of numerical abundance since it contributed about 70% of the total zooplankton.

The lowest species diversity was shown by the cladocerans, of which two species were recorded and contributing about 10%. Next to Lake Katwe was Kirumi Pond where fifteen species were identified. Among the sampled water bodies, Lake Kirumi showed the highest diversity of cladocera, five species being recorded. The main component was *D. excisum* which contributed 15% of the total zooplankton numerical abundance followed by D. *lumhortzi* (7%) and *C. cornuta (*6%). *Chydrorid* spp. and *M. micrura* contributed 1% each.

The calanoids were not widely distributed. They were found in Kyarano Dam and River Mara only. It is surprising that the calanoids were absent even in Kirumi Pond where some water from the river flows in. In Lake Ikimba the Cladocerans were absent, and the zoolplankton community was dominated by cyclopoid copepod. They comprised more than 95% of the total numerical abundance. Two species of rotifers were also found but in relatively very low numbers. The same was observed in Lake Malimbe, in which the cladocerans were absent in the open waters but two species were encountered in the littoral areas *B. longirostris* and *Chydorid* spp. Rotifera comprised four species and there were no calanoid copepods. There is therefore, a marked scarcity of adult filter feeders in Lake Ikimba and Lake Malimbe. Cyclopoid copepodites are raptorial feeders which grasp their food. They are thus better able than filter feeders to utilize the large particles, which may dominate in the phytoplankton of those lakes.

The cyclopoid *T. tenellus* were the most abundant members of the zooplankton community in Mara River, this pattern being different from other lakes where the *Thermocyclops* were always dominant. *T. tenellus* are the smallest among the Cyclops. This may be to the advantage of their survival, as the predators do not prefer them.

Kubigena Ox-bow Lake was very shallow and turbid. The rotifers were very important in terms of species diversity as well as numerical abundance. The most common species was *Brachionus patulus* which contributed 23% followed by two cladocerans, *M. micrura* (18%) and *D. exisum* (10%) of the total zooplankton numerical abundance.

In terms of abundance Kyarano Dam contributed the highest density. The zooplankton mean abundance reached 179,689 m^{-2}. Copepoda was the most important group and contributed about 56% followed by cladocera (40%) and rotifera (about 4%). The dominant species was *D. excisum*, which contributed 38% of the total zooplankton abundance, followed by *T. emini* (23%). Among the rotifers, *Brachionus* was the common genus. After Kyarano Dam, Lake Burigi had the next highest density, with a zooplankton mean abundance of 106,359 m^{-2}. It was dominated by the copepod, which comprised about 96% of the total zooplankton. The most common species were *T. emini* and *T. neglectus*. *D. excisum* was the only species of Cladocera observed in the lake. Only two species of rotifer were observed in Lake Burigi *Ascomorpha* species and *B. calyciflorus*. This lake is a clear lake without macrophytes. Most rotifers are not planktonic, but are sessile and associated with littoral substrata (Wetzel, 1983). Population numbers are highest in association with submerged macrophytes, especially plants with finely divided leaves (Edmondson, 1944; 1945; 1946). This is probably the reason why only few rotifer species were found in Lake Burigi. The absence of

Cladocera in the lake may be because they are eaten by many young fish, and also by the larvae of the dipteran chaoborus which were also found in the sample. The same findings were observed in Lake George (Burgis *et al*., 1973).

The cyclopoids were the most common species in the lake, the zooplankton population structure showing a tendency of predation pressure caused by fish as well as micro invertebrates most probably the chaoborid larvae and caridina which were found in large numbers comprising 25% of the total zooplankton numerical abundance in the littoral area. Two *Thermocyclops*: *T. emini* and *T. neglectus* were the dominant cyclopoid and contributed 24% and 32% of the total zooplankton numerical abundance. *T. confinnis* were rare. One species of Cladocera *D. excisum* and two species of rotifers *B. calyciflorus* and *Ascomorpha* species were encountered. The structure and composition trends of zooplankton in this lake may be related to both intensity of predation and limitation by environmental factors, which may include food quality and quantity.

In almost all the lakes cyclopoid copepod were the dominant group except in Lake Kubigena and Lake Malimbe, where rotifera were the dominant group. This was probably because of the nature of the lakes. These lakes are shallow about 0.4 m and 2.5 m respectively, a condition which is preferred by rotifers. The cladocera *D. excisum* was widely distributed and presented in all lakes except Lake Ikimba and Lake Malimbe.

During this study zooplankton numerical abundance was higher in Kyarano Dam, Lake Katwe, Ikimba, Malimbe, Buswahili and River Mara. Temperature increase may be the reason for that. During this cruise, the water was warm, about $25^{o}C$, compared to that of June 2000 (Waya 2001 in press). This may have an effect on the development times of the copepods and cladoceran eggs as development of these eggs appear to be wholly dependant on temperature (Bottrel *et al.*, 1976; Vijverberg, 1980; Irvine and Waya, 1995). Temperature is important mainly because it influences the egg development time, growth rate, brood size and mortality of zooplankton (Hall, 1964, Herzig, 1994). The egg development rates increase as temperature increases. This may have caused the abundance to be higher in this study.

The study of March/April 2001 was done during and immediately after the rainy season. In almost all water bodies the densities of zooplankton were higher ranging from 31,108 m^{-2} in Kubigena Oxbow Lake to 479,015 m^{-2} in Lake Ikimba. This was probably due to the influent flood waters in the sampling areas which had relatively high nutrient concentration. The nutrents may have resulted in an increase in phytoplankton production. Zooplankton would increase in abundance due to increased food availability (Masundire, 1994). The diversity was also higher than the previous study, as thirty two species were encountered while in the previous study only twenty four species were observed.

The highest species diversity was observed in Lake Katwe, where twenty species were identified. Among them rotifera contributed twelve species, the most common one being *K. tropica* which contributed 17% of the total zooplankton numerical abundance. Next to rotifera was copepoda, the most common one being the cyclopoid copepod *T. neglectus* which was accounted for 16% of the total zooplankton numerical abundance. The nauplii were numerous contributing 39%. The cladocerans were very rare in the sample, the commonest one being *M. micrura*. In the littoral area, rotifers were numerous and contributed 74% of the total zooplankton numerical abundance. *Brachionas* and *Keratella* were the most common genus. The *Brachionids* were *B. angularis* (17%), *B. calyciflorus* (1%) and *B. caudatus* (8%), *Keratela* species were *K. tropica* (26%) and *K. cochlearis* (8%). Another common spicies were *L. bulla* (3%), *F. opoliensis* (4%) and *Asplanchna* spp. (3%). Other species were rare. The small and the transparent cladocera *M. micrura* contributed 8% of the total zooplankton numerical abundance. Next to rotifera was copepoda, the commonest one being the Cyclopoid copepod *T. neglectus* which accounted for 16% of the total zooplankton numerical abundance. The cladocerans were very rare in the sample, the commonest one being *M. micrura*.

Next to Lake Katwe was Kubigena Oxbow Lake. Among the eight species observed, eleven were rotifers. *Brachionus* was the most common genus and it contributed three species; *B. Caudatus, B. angularis* and *B. patulus* which accounted for 9%, 3% and 2% respectively. Other common rotifers were *L bulla* (6%), *Asplanchna* spp. (6%), and *K. cochlearis* (3%). In this lake cladocera were also found, the most common ones being *B. longirostris* and *D. excisum* each of them contributing 5% of the total zooplankton numerical abundance. Together with zooplankton, chaoborid larvae and ostracords were also present in the sample. The copepoda were present in the sample but not many, although the nauplii were numerous. This indicated that the lake condition was not good enough to allow the post-naupliar development stages to be completed. This was the only lake where the copepods were rare.

In Kyarano Dam, seventeen species were encountered Rotifera contributed eight species although they were not many in number. The most common rotifer was *K. cochlearis,* accounting for 7% of the total zooplankton numerical abundance. Copepoda contributed six species. The cyclopoid copepod *T. emini* was the most common species and contributed 12% of the total zooplankton numerical abundance. This is the only lake where the calanoid copepod *T. galeboides* was encountered. *D. excisum* was the most common cladocera and it contributed 5% of the total zooplankton numerical abundance.

In River Mara, 16 species were observed. Zooplankton density was much higher at shallow station than at the deeper stations. Neither cladocera nor copepoda were observed in deeper waters, only rotifers and ostracords, which were present in the sample and contributed 50% of the total zooplankton numerical abundance. The same observation was made in the Sanyati basin of Lake Kariba (Masundire, 1994). He reported that after about five weeks of being ‘flooded’, the only crustaceans observed were ostracords. In shallow water the density of zooplankton was higher, and rotifera, copepoda and cladocera were all present, the most numerous species being the cyclopoid copepod, *T. emini*, accounting for 24% of the total zooplankton numerical abundance, followed by the cladocera *D. excisum* which contributed 18%. The most common rotifera was *L. bulla* contributing 3.6%. The reason for the higher density at shallow water may be because deeper stations have a large volume of water which will cause greater dilution of nutrients brought up from the bottom at deep stations than at shallow stations. The result will be higher post turn over nutrient concentration at shallow areas, which will cause an increase of food availability of zooplankton.

In Lake Burigi, sixteen species were identified. Rotifera was the most important group in terms of diversity and contributed eight species. In the open waters, the rotifers were not many but in the shallow areas they contributed 52% of the total zooplankton abundance. The most common genus was *Keratela* which contributed 31% of the total zooplankton numerical abundance. The species identified were *K. cochlearis* (5%), *K. tropica* (22%) and *K. quadrata* (4%). Another common species was *F. opoliensis* accounting for 10%. In the open waters the copepoda were very common. *Thermocyclops* were the most common genus accounting for 26% of the total zooplankton abundance. Two species *T. emini* and *T. neglectus*, were the most important species in terms of abundance.

The highest density of zooplankton were observed at Lake Ikimba, where the abundance reached 476,015m^{-2}. It seems that there are no predation pressure on zooplankton, even fishermen were complaining that there are no fish in the lake (Pers. Comm.) Copepoda were most numerous, the mostcommon species being *T. neglectus*. The rotifers contributed the highest number of species, ten species being encountered, and *K. tropica* was the most common species. Cladocera were absent in the open waters, and only *Bosmina longirostris* were observed in the littoral areas.

Lakes Malimbe and Kirumi contributed the lowest number of species, as only twelve species were found in each lake. The zooplankton numerical abundance was also low. In both lakes, no cladocera were observed in the open waters. The only copepod found in these lakes was *T. emini*. In Lake Kirumi the most common rotifer was *Asplanchna* species which contributed 21% of the total zooplankton numerical abundance, while other common species were *B. angularis, Synchaeta* spp. and *Ascomorpha* spp. which contributed 13%, 5% and 3% respectively. In lake Malimbe the most common rotifer was *B. angularis* which accounted for 18% of the total zooplankton numerical abundance. Other common species were *Asplanchna* spp., *B. Calyciflorus*, *K. Cochlearis* and *K. tropica*. In the littoral areas, high densities were observed in these lakes; in Lake Kirumi, 172,998 m^{-2} and in Lake Malimbe 113,377 m^{-2}. Four cladocerans were encountered in Lake Kirumi and were dominant, contributing 45% of the total zooplankton numerical abundance. Next to *D. excisum* is the *Asplanchna* spp, which contributed 16%. *Synchaeta* spp. was also common. It contributed 14% of the total zooplankton numerical abundance. In Lake Malimbe, the only cladocera was *D. excisum*.

Among the cladocerans, *Ceriodaphnia cornuta, D. excisum* and *M. micrura* were wide spread in the water bodies surveyed. They were found in at least four locations. These species were also found in most tropical fresh waters (Dumont, 1994; Korovchinsky, 1992; Austin *et al*., 1994). *Moina micrura* have the advantage of being small and transparent, therefore they are relatively immune to fish predation, although they may suffer substantial losses due to invertebrate predators (Dumont, 1994). That is why their occurrence in Lake Katwe, River Mara, Lake Kirumi and Kubigena Oxbow Lake was not low. *B. Longirostris, Chydorid* spp., *D. Lumhortzi* and *Alona* spp. were rare species.

Alona species were found in Lake Kirumi only. In tropical lakes and flood plains, the littoral offers a year round site for higher densities of micro and meso-plankton (Fernando, 1994). This has been true in Lakes Kirumi and Malimbe, and in River Mara, the densities of zooplankton being much higher in the littoral than in the open waters. The numerical abundance of zooplankton was relatively higher in this study because of the high densities of nauplii and rotifers. This may be because of the amount of nutrients available as well as the type of gear used. The mesh size of the net was 65 µm, and this was able to collect early copepodites, nauplii and rotifers. Also the predation of fish does not affect them much because normally fish select larger prey that they can catch and digest. The larger the prey, the greater the chance of being caught. The visual predators must see their prey to catch it, so objects smaller than about 1mm are not really seen, and thus the rotifers, small cladocera such as *Bosmina*, nauplii and early copepodites will escape (Moss, 1998).

The copepoda were widely distributed and were the most common group in almost all the lakes, while the cladocera were very rare, especially the large cladocera which are most vulnerable. They move slowly and probably do not have sensory mechanisms capable of detecting the shock wave of an approaching fish. In contrast, the copepods have sensory hairs on their antennae. With a flick of their abdomens, they can move away with great speed from the line of attack by the fish (Lynch, 1979). This can explain their success in the lakes surveyed.

It seems that there is no competition among grazers in the surveyed lakes. Large Daphnia species, which could compete with small rotifers, were absent in almost all lakes. Smaller cladocerans such as *Bosmina* may co-exist with rotifers because they are not powerful feeders. Small cladocerans may also be more vulnerable to invetebrate predation which prevents rises in populations to a competitive level (Moss 1998).

This pattern of zooplankton structure and composition in some Tanzanian Lake Victoria Basin water bodies is similar to that in some of the Ugandan satellite lakes, (Ndawula and Kiggundu, unpublished report), in Kyoga satellite lakes (Kawi, Lemwa, Nyaguo, Nakua, Agu, Gigate and Nawampasa), Lake Wamala, Lakes Nabugabo and the satellite lakes of Kayugi and Kayanja, and River Nile and that of Kenyan satellite lakes (Masai 2001 in press). Rotifers supported higher species diversity just as has been observed in this study. In most of the Ugandan satellite lakes, the most common rotifers were *Keratella tropica, Brachionus caudatus, and Tricocerca*, which were also common in this study. One species *Macrothrix laticornis* was observed in Lakes Agu and Nawampasa but was not found in the surveyed water bodies. *Thermocyclops neglectus* was the most common copepod in Tanzania and Uganda, but *Thermocyclops emini*, and *Diaphanosoma excisum* were not common crustaceans in Ugandan satellite lakes. *Diaphanosoma excisum* were common crustaceans in Tanzanian and Kenyan satellite lakes. No calanoids were observed in dams in Kenya (Masai, 2001) but in Tanzania calanoids were found in Kyarano dam and River Mara (Waya, 2001).

CONCLUSION

This study revealed that three major groups of zooplankton exist in the satellite lakes i.e. copepoda, cladocera and rotifera; overall 21 genera and 33 species were identified. The dominance of the cyclopoid copepod was a common trend in all water bodies surveyed except Kubigena Ox-bow Lake and Lake Malimbe where the rotifers dominated. Rotifers were always important in terms of species diversity. Lake Katwe is species rich, and contributed the highest number of species compared to other lakes in both studies. In terms of numerical abundance, Kyarano Dam contributed the highest density in September/October 2000, the mean total number being 179,689 m^{-2} . In March/April 2001 the highest density of 479,015 m^{-2} was observed in Lake Ikimba. Generally the density of zooplankton was higher in September/October 2000 than in March/April 2001.

RECOMMENDATIONS

i. Studies on the population dynamics and production of zooplankton are useful because the quantification of zooplankton production assists in the understanding of fisheries production and perhaps of more importance, of the nature of ecosystem trophic dynamics in aquatic ecosystems.
ii. Also there are no identification keys for the Lake Victoria invertebrates. It is therefore recommended that this be worked on, especially for copepods which are a very complicated group.

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The effects of different diets on the growth performance of Tilapia, *Oreochromis variabilis* (Boulenger, 1906) fry under aquaculture conditions

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Abstract

The effects of different diets on the growth performance of *Oreochromis variabilis* (L.) fry (Osteichthyes: Cichlidae) were investigated in a hatchery. The diet trial experiment was conducted in modified 1000 litre circular polytex tanks. *O. variabilis* fry were fed on different diets for 184 days. The diet that contained cotton seed cakes as the main ingredient showed significantly ($p<0.05$) better growth performance than the soyabean meal and composite diet. Fishmeal control diet showed no significant difference ($P>0.05$) over cotton seed cakes. The overall mean (mean ± se) survival rate was 89 ± 1.74% and was not influenced by diets.The conclusion reached was that diets contained cotton seed cakes could be used as an alternative diet in feeding *O. variabilis.* This conclusion is based on the fact that growth performance on cotton seed cake was better than other diets in this study and it is cheaper than fishmeal.

Key words: Oreochromis variabilis, Diets, Growth, Aquaculture, Tilapia.

Introduction

Supplementary feeding is an important tool for augmenting fish production. In fish nutrition, protein is an important ingredient because of its influence on growth and its direct relationship to diet cost. . There are 13 amino acids that are essential for building new tissues in fish (Bowen, 1982). These amino acids cannot be synthesised by fish and must be obtained from the diet. Usmani *et al*. (1997) noted that another major problem in aquaculture is the limited supply and increasing cost of fishmeal, an important source of animal protein in formulated fish feeds.

Development of Aquaculture in rural Africa including Tanzania is limited because of cost, shortage of fish feeds and pond fertilisers, poor financial resources and basic knowledge (i.e. management techniques such as feeding etc.) of small-scale farmers. Considerable success has been achieved in the development of artificial fish diets in temperate fish species (Cho *et al*., 1976; Tacon *et al*., 1983). In the developing countries formulation and preparation of feed has become a major expenditure in fish farming practices (Wanda *et al.*, 1991). Hence, use of natural feeds may increase the survival and growth rates of juveniles (Wanda *et al*., 1991) and reduce the cost of feed.
According to FAO (1994), many indigenous fish species are preferred by consumers but have not yet been fully tested as candidate species for aquaculture. The indigenous Tilapia, *O. variabilis* is one of the cichlid fishes endemic to Lake Victoria.

The present study investigated the effect of soybean, cottonseed cake and *Azolla niloticus* based diet on growth and survival rates of indigenous Tilapia, *O. variabilis.*

Materials and method

Study Site

The study was conducted at the Tanzania Fisheries Research Institute (TAFIRI) hatchery at Nyegezi, in Mwanza, Tanzania.

Source of Experimental Animals

Juvenile *O. variabilis* was used in this study. The broodstock was obtained from Mkuyu dam in Migori district, Nyanza Province in the Republic of Kenya with the assistance and authority of Kenya Marine and Fisheries Research Institute (KMFRI). The collection and transportation of fishes was done as recommended by Mgaya and Tamatamah (1996) and Collart (1997). At Mkuyu dam the fish were caught in a single haul using a beach seine net. The fishing activity was conducted in the early hours of the day, from 5:00 am to 6:30 am after which the fish were transported to Mwanza. This took about six hours. Upon reaching Mwanza the fish were released into the storage concrete tanks to acclimatise. The brood stock was left in the receiving tanks for several days where they were fed on fish meal ("dagaa") *ad libitum*. The brood fish were stocked in the nearby fish ponds, where they grew and reproduced. The fry obtained from these brood stocks were then used for the dietary trial experiment of this study.

Experimental Diets

Cottonseed cake (*Gossypium hirsutum* (L.)) and Soybeans (*Glycine max* (L.)) were used as a source of protein whereas *Azolla niloticus* was used as both protein source and energy source in compound feeds. In addition Cassava (*Mannihot esculenta* C.) was used as an energy source. 'Dagaa' fishmeal (*Restrineobola argentea*) was used as a control diet.

Sources of Experimental Diets

The cotton seed cakes were purchased from an oil ginnery known as VOIL in Mwanza City. The soybean seeds were purchased from a local market in Mwanza City whereas cassava was purchased from a farmer at Luchelele village close to Mwanza City. *Azolla niloticus* was collected from the shores of Lake Victoria by using scoopnet and transported in plastic bags into the nearby fish ponds where they were inoculated. Dagaa was purchased from fishers at Kirumba fish market, Mwanza.

Preparation of Experimental Diets

Cotton seed cake (*Gossypium hirsutum* (L))

The cotton seed cakes were dried, milled and stored before they were incorporated in feed formulations.

Soybean seeds (*Glycine max* (L))

Mature dry seeds of soybean seeds were sorted manually for any impurities. The seeds were then soaked for 24 hours in clean tap water at the seed : water ratio of 1:3 on a volume basis. There after the soaked seeds were boiled in water at the seed : water ratio of 1:2 by volume basis for about 45 minutes. Boiling of soybeans was meant to eliminate the enzymes that inhibit the digestion of leguminous plant protein in fish. The soaked and boiled seeds were washed using clean tap water and spread on a polythene sheets for sun drying for about 72 hours before being milled and stored ready for incorporation in feed formulations.

Azolla niloticus

After three to four weeks the already flourished *A. niloticus* in the fish ponds were harvested by a scoop net and carried in plastic buckets into the polytex tanks. In the polytex tanks *A. niloticus* was washed using clean tap water to remove the adhering dirt and sand. Thereafter *A. niloticus* was spreadout to dry in the sun (on a drying floor made of slightly rough cement) in a layer of 5-10 cm thick and turned over 2-3 times a day (Collart, 1997). It took up two to four days to dehydrate the *Azolla*. The dehydrated material was then minced using a meat mincer and sieved before it was incorporated in feed formulations.

Restrineobola argentea "Dagaa" (Fishmeal)-control diet

The fishmeal described here refers to the ground pelagic "Dagaa" *Resrineobola argentea* obtained from Lake Victoria. The dried "Dagaa" was milled and incorporated in feed formulations.

Cassava (Mannihot esculenta)

Cassava roots were pealed, sliced to small pieces before being spread on the floor to dry as used for *A. niloticus*. The dehydrated cassava was milled and stored ready for incorporation in feed formulations.

Proximate analysis of the ingredients of the experimental diets

The samples of the ingredients of the experimental diets were analysed for crude protein, ether extract (crude fat), crude fibber, ash and total carbohydrate following the AOAC (1984) procedure. Crude protein was analysed by continuous extraction using petroleum ether (40 ^{o}C – 60 ^{o}C B.P) and diethyl ether (34 ^{o}C – 36 ^{o}C B.P) in Soxhelt. Total carbohydrate was calculated by difference i.e. 100 - (% crude protein + % ether extract (fat) + % crude fibre + % ash). The proximate composition analysis is shown in Table 1. The proximate composition analysis was carried out at the Department of Animal Science and Production of the Sokoine University of Agriculture (SUA) in Morogoro, Tanzania.

Table 1: Proximate composition analysis of the ingredients of the experimental diets

Ingredients	**% crude protein**	**% crude fibre**	**% Crude fat**	**% ash**	**% dry matter**	**% carbohydrate**
Azolla niloticus	23.79	11.10	2.80	11.64	88.71	39.38
Cotton seed cakes	35.70	17.60	12.07	7.22	93.48	20.89
Soybeans	42.23	7.40	20.50	4.03	94.21	19.95
Dagaa	58.71	0.32	16.11	16.01	92.04	0.89
Cassava	1.3	0.00	0.10	2.3	0.00	84.3

Formulations of experimental diets /feeds

The proximate composition of protein of each ingredient (Table1) were used in the Simple Pearson square method as described by New (1987) to standardise the protein levels and complement with the basal feeds to supply energy. Each treatment (except for the control diet) was mixed with 0.1% Vitamin-mineral mix as recommended by New (1987). The formulated diets were then proximate analyzed for crude protein, crude fate (ether extract), crude fibre and total carbohydrate (Table 3). The prepared fish feeds were stored in a cool and dry area.

Table 3: Formulation and proximate composition (% dry matter basis) of experimental diets.

Ingredients (g)/100g diet	D_1*	D_2*	D_3*	D_4*
Dagaa 'Fishmeal'	0.00	0.00	0.00	100.00
Soyabean meal	48.19	0.00	94.30	0.00
Cotton seed cake meal	48.19	89.91	0.00	0.00
Azolla niloticus	1.76	0.00	0.00	0.00
Cassava	1.76	9.99	5.60	0.00
**Vitamin/mineral mix	0.10	0.10	0.10	0.00
Totals	100.00	100.00	100.00	100.00
Proximate analysis of Diets (% dry diet)				
% Dry matter	91.98	92.89	91.30	92.04
% Crude protein	47.04	51.19	40.26	58.71
% Crude fibre	16.28	12.23	7.08	0.32
% Crude fat	14.21	9.88	18.46	16.11
% Ash	6.21	9.30	3.55	16.01
% Carbohydrates	7.72	10.39	21.95	0.89

*D1= Soyabean meal + cotton seed cake meal + *Azolla niloticus* + cassava + vitamin/mineral mix; D2=Cotton seed cake meal + Cassava + vitamin/mineral mix; D3 = Soyabean meal + cassava + vitamin/mineral mix; D4 = 'Dagaa' Fishmeal.

**Vitamin/mineral mix: Vitamin A (15,250,000 iu); Vitamin D_3 (4,500,000 iu); Vitamin E (1,335 iu); Vitamin K (4,500 mg); Vitamin B_2 (4,500 mg); Vitamin B_6 (2, 350 mg);Vitamin B_{12} (11,500 mcg); Vitamin C (1,000 mg); Niacin (16,750 mg); Pantothenic acid (5,375 mg); Methionine (10,200 mg); Lysine (15, 250 mg); Zinc Sulphate (12, 250 mg); Copper Sulphate (12,250 mg); Manganese Sulphate (12,250 mg); Magnesium Sulphate (912, 250 mg); NaCl (50,000 mg).

Preparations and operations in the experimental tanks

In the experimental culture systems the replicates were arranged in random block design. Water was supplied from the overhead tanks into the experimental tanks. Before stocking the fish, the tanks were washed thoroughly with fresh water. The tanks were then filled with sand up to 3 cm deep to simulate the condition that *Oreochromis variabilis* is accustomed to in nature. The tanks were left to dry for a week before being filled with fresh water. The water level in the experimental tanks was maintained at 200 l. The compressor was used to supply oxygen into the experimental tanks throughout the experiments except when there was power breakdown. In addition water replacement of 40 % per week was adopted to ensure adequacy of dissolved oxygen.

Each individual tank contained 200 fry at a stocking density of 1 fry per litter. The fish fry were acclimatised in the experimental tanks while feeding on control diet (fishmeal) for two weeks.

Feeding regime

The feeding of 5% of fish body weight per day, as used by Mabrouk *et al*. (2000) was adopted. Revised feeding allowances were calculated on the basis of the total weight of the fish calculated from the mean weights. The revised feeding allowances were done every 14 days. Thus feeding levels were according to the number and size of the fry in a given tank. The feed was divided into two rations. Half of the ration was given between 0730 and 0800 hrs and another half between 1830 and 1900 hrs. Feeding regime of twice a day i.e. morning and evening has been shown to have a higher feed conversion efficiency (Hepher, 1988). Before fresh food was given, faeces and uneaten food was removed by using a scoop net made out of cloth material. Feeding of fish was done by hand as this method enables regular inspection of the fish (New, 1987). Four dietary treatments including the control diet were tested. Three replications (4T x 3R) per treatment (feed) were adopted. The main ingredients in the tested diets included a mixture of Soyabean meal, cotton seed cake and *Azolla niloticus* (D1), Cotton seed cakes meal (D2) and Soyabean meal (D3). "Dagaa" fishmeal (D4) was used as the control diet. Cassava was maintained to enrich the carbohydrate of the diet.

Data collection

Fish growth

In order to assess the growth performance, records of both average individual fish weights and cumulative weights were progressively taken in each fry tank. A sensitive electronic balance (Libror EB-620s SHIMADZU) was used to record weights. A sample of 30% of the stocked fish was taken randomly from each fry tank by using a scoop net. The fish fry were weighed and returned into their respective fry tanks. The fry were blot-dried before weighing as recommended by Anderson and Gutreuter (1983). To avoid the effects of wind on the weighing balance all the windows and doors in the weighing room were closed (Anderson and Gutreuter, 1983). Sampling was done every 14 days and herein sampling period will refer to two weeks period. There was no feeding during sampling. The following growth variables were determined:

a)

(Hopkins, 1992).

b)

(Castell and Tiews, 1990)

c.

d.

(Zeitoun *et al*., 1973; Castell and Tiews, 1990).

e.

Water Quality Variables

Water quality variables were monitored daily. Water temperature, dissolved oxygen and pH were recorded using a water quality checker (model U-10 Horiba, Japan). This was done by immersing the probe into the water. The measurements were taken twice a day during the morning (between 0630 and 0730 hours) and during the evening (between 1730 and 1830 hours). From the daily data, mean values of each variable were calculated in every 14 days. The percentage of un-ionised ammonia (UIA) was calculated from the following relationship as adopted by Ayinla *et al*., (1994):

UIA = 100 / 1+antilog (pKa-pH)

Where:

$pH = -\log(H_3O^+) = -\log(H^+)$

pKa = -logKa = constant = 9.25

Data Analysis

Data analysis was done with the Statistical Analysis System (SAS) General Linear Models Procedure (GLM) (SAS, 1992). The performance in growth variables (i.e. specific growth rate, feed conversion ratio, feed conversion efficiency, protein efficiency ratio and survival rates) of *O. variabilis* cultured under different diet treatments was analysed. Coefficients among the dependent variables investigated were analysed by using Multivariate Analysis of Variance (MANOVA) (which gives the post test where a significant difference between the dependent variables is detected). The data on survival rates (%) were analysed using the Instant Statistical package after arcsine transformation to guard against violation of assumptions of ANOVA.

Two statistical models were used to analyse the data. The first model involved an individual fish as an observational unit where as the second model involved a fry tank as an observational unit.

Growth of Fish

The statistical model used to study the effects of different treatments on the growth performance of fish was as follows:

$Y_{ijk} = \mu + T_i + R_{ij} + e_{ijk}$

Where:

Y_{ijk} = observation from the k^{th} fry in the j^{th} replicate fry tank receiving the i^{th} feeding type.

μ = general mean common to all observations in the study.

T_i = effect of the i^{th} feeding type.

R_{ij} = effect of the j^{th} replicate fry tank receiving the i^{th} feeding type.

e_{ijk} = random effect peculiar to each fry.

Cumulative weights and growth variables

The following statistical model was adopted in analysing these variables:

$Y_{ijk} = \mu + T_i + R_{ij} + e_{ijk}$

Where:

Y_{ijk} = record on individual k^{th} fry tank
μ = general mean common to all tanks in the study
T_i = effect due to i^{th} feeding type
R_{ij} = effect contributed by the j^{th} replication within the i^{th} type of feeding
e_{ijk} = random effect peculiar to each fry.

Testing of the Main Effects in the Study

The main effects (cumulative weights and growth variables) in the present study were tested using replication as an error term since the analysis of GLM procedure had shown a significant difference ($P<0.05$) in growth performance of fish within replications. Therefore replication was used as an error term to take care of that situation and as such reduce the variation between replications.

Results

The coefficient of determination (R^2) for most variables ranged from 0.72 to 0.89 (Table 2). This reflects that over 70% of the variation in most of the variables measured in this study could be explained by the analytical models adopted. The coefficient of variation (CV) for most variables ranged from 9 to 19% (Table 2). This is a reflection that the experimental material used in the study was fairly homogenous, leave alone the variations caused by experimental treatments.

Table 2: Statistics and number of surviving *O. variabilis* (Boul.) fry reared under different diets (D).

Periods (two weeks @)	Diets D1			D2			D3			D4 (Control)			Statistics R^2	CV
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3		
1	180	190	197	198	198	199	180	198	199	166	165	195	0.89	18.71
2	130	120	128	130	181	140	160	160	130	170	156	100	0.84	9.29
3	99	99	109	86	166	128	130	135	95	140	122	90	0.62	9.36
4	90	92	102	80	152	123	124	129	92	135	118	87	0.46	11.34
5	87	88	96	80	148	118	121	112	87	129	112	93	0.72	12.40
6	82	85	91	75	138	110	113	109	78	121	109	77	0.88	11.50

D=diets R=replication

Growth in Weights

The growth performance of *O. variabilis* fry fed on different diets is illustrated in Figure 1. Cotton seed cakes diet (D2) showed the highest cumulative weight (34.51 ± 3.68 g) compared to composite diet (D1) (31.15 ± 3.68 g) and Soybean diet (D3) (31.18 ± 3.68 g) during the first two weeks of experimentation. However there was no significant difference in growth between cumulative weights ($P>0.05$) during this rearing period. During the second, third, fourth, fifth and sixth two weeks of experimentation D2 showed highest cumulative weights compared to D1 and D3. During this period the results showed significant difference ($P<0.05$) in cumulative weights except during the fifth two weeks. During the fifth two weeks of experimentation there occurred a fungi disease. During the whole period of experimentation, fishmeal (control diet, D4) showed highest cumulative weights of all other diets. However, when Cotton seed cakes diet (D2) was compared with fishmeal (control diet, D4), the results showed no significant difference ($P>0.05$).

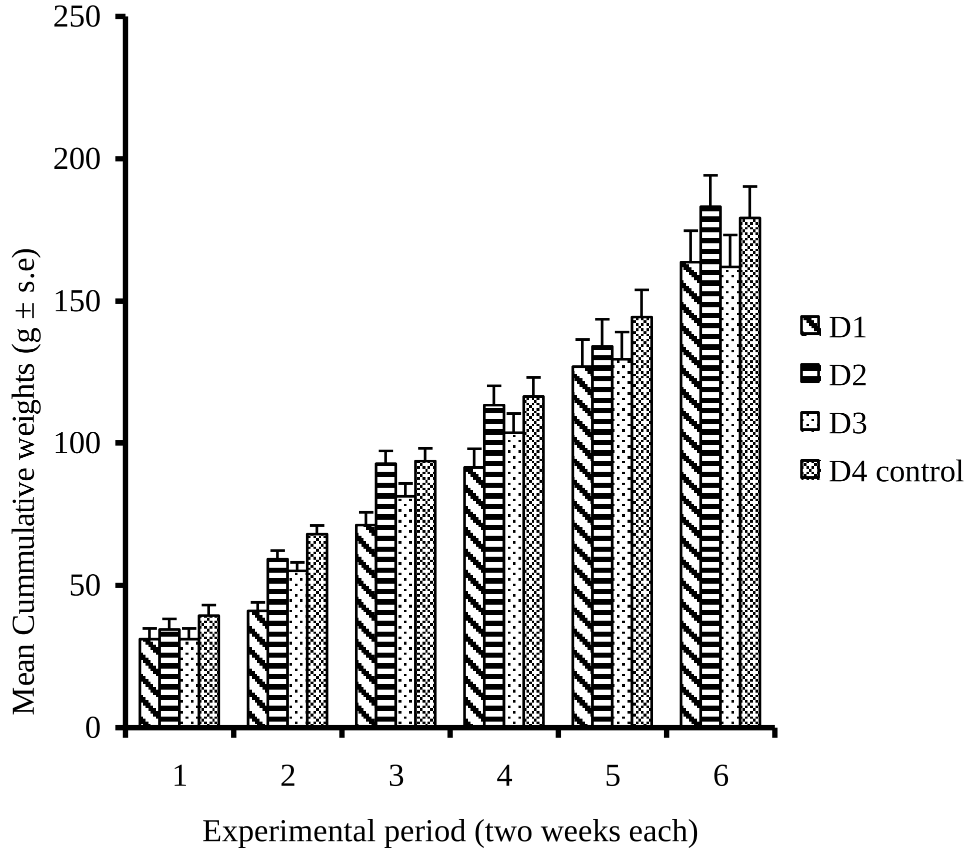

Fig. 1: Mean cumulative weights (g ± s.e) of *Oreochromis variabilis* fry fed on different diets for twelve weeks in polytex tanks. Vertical bars indicate standard errors.

The results show an increase in cumulative weights from the beginning to the end of experiment. The results of multivariate analysis of variance (MANOVA) are presented in Table 4. There was a significant difference (P<0.05) between cumulative weights at the beginning of experiment and at the end of experiment. However, there was no significant difference in cumulative weights (P>0.05) between sampling one and four, two and three and between sampling period five and six in all experimental diets.

Table 4: ANOVA table showing the partial correlation coefficients for the weights used in the analysis

Cumulative weights (CW)	Cumulative weights (CW)					
	CW1	CW2	CW3	CW4	CW5	CW6
CW1	1.00					
CW2	0.007*	1.00				
CW3	0.006**	0.065	1.00			
CW4	-0.062	-0.055***	0.034***	1.00		
CW5	-0.042***	0.018***	0.059***	0.006***	1.00	
CW6	-0.046***	0.016***	0.043***	0.008***	0.414	1.00

significant at (P<0.05), ** significant at (P<0.01), *** significant at (P<0.001)

Growth Variables

The growth performance of *O. variabilis* fry fed on different trial diets with respect to Specific growth rates (SGR), Food Conversion Ratio (AFCR), Food Conversion Efficiency (AFCE) and Protein Efficiency Ratio (PER) is presented in Table 5. D2 showed the highest SGR, AFCE, and PER with better AFCR when compared with other diets, except during the second two weeks of experimentation. The results showed that there was significant difference (P<0.05) in growth variables between trial diets except during the first two weeks. The comparison between cotton seed cake meal (D2) and fishmeal (D4) showed no significant difference (P>0.05) in growth variables during the second two weeks. However, there was significant difference (P<0.05) between D2 and D4 during the rest of the period of experimentation.

Table 5: Least square means for growth variables of *O. variabilis* (Boul.) fry fed on different trial diets

Periods (two weeks each)	Variable	Diets			
		D1	D2	D3	D4 (Control)
1	SGR (%)	4.40 ± 0.68	5.07± 0.68	4.39 ± 0.68	5.92 ± 0.68
	AFCR	0.84 ± 0.11	0.71 ± 0.11	0.85 ± 0.11	0.59 ± 0.11
	AFCE (K_1%)	122.05 ± 31.27	150.6 ± 31.27	122.28 ± 31.27	191.66±31.27
	PER	1.57 ± 0.40	1.93 ± 0.40	1.57 ± 0.40	2.46 ± 0.40
2	SGR (%)	1.98^{a} ± 0.50	3.90^{b} ± 0.50	4.08^{b} ± 0.50	4.03^{b} ± 0.50
	AFCR	2.20^{a} ± 0.18	0.99^{b} ± 0.18	0.94^{b} ± 0.18	1.03^{b} ± 0.18
	AFCE (K_1%)	75.72^{a} ± 17.95	104.68^{b}± 17.95	111.18^{b}± 17.95	111.52^{b}±17.95
	PER	0.59^{a} ± 0.23	1.34^{b} ± 0.23	1.43^{b} ± 0.23	1.43^{b} ± 0.23
3	SGR (%)	2.59^{a} ± 0.25	3.91^{b} ± 0.25	2.78^{a} ± 0.25	2.31^{a} ± 0.25
	AFCR	1.67^{a} ± 0.15	0.98^{b} ± 0.15	1.53^{a} ± 0.15	1.84^{a} ± 0.15
	AFCE (K_1%)	56.94^{a} ± 8.04	101.83^{b} ± 8.04	78.38^{a} ± 8.04	54.46^{a} ± 8.04
	PER	0.73^{a} ± 0.10	1.35^{b} ± 0.10	0.88^{a} ± 0.10	0.70^{a} ± 0.10
4	SGR (%)	1.74^{a}± 0.25	2.84^{b}± 0.25	1.73^{a}± 0.25	1.56^{a} ± 0.25
	AFCR	2.80^{a}± 0.43	1.05^{b}± 0.43	2.60^{a}± 0.43	2.90^{a} ± 0.43
	AFCE (K_1%)	49.78^{a}± 6.31	96.39^{b}± 6.31	39.29^{a}± 6.31	34.93^{a} ± 6.31
	PER	0.51^{a}± 0.08	1.49^{b}± 0.08	0.50^{a}± 0.08	0.45^{a} ± 0.08
5	SGR (%)	1.33^{a}± 0.21	2.57^{b}± 0.21	1.53^{a}± 0.21	1.54^{a} ± 0.21
	AFCR	1.89^{a}± 0.33	1.23^{b}± 0.33	2.98^{a}± 0.33	3.02^{a} ± 0.33
	AFCE (K_1%)	55.64^{a}± 5.60	65.19^{b}± 5.60	34.12^{a}± 5.60	34.42^{a} ± 5.60
	PER	0.71^{a}± 0.07	1.45^{b}± 5.60	0.44^{a} ± 5.60	0.44^{a} ± 5.60
6	SGR (%)	1.84^{a} ± 0.12	1.85^{b} ± 0.12	1.63^{a} ± 0.12	1.22^{a} ± 0.12
	AFCR	2.42^{a} ± 0.27	1.53^{b} ± 0.27	2.76^{a} ± 0.27	3.83^{c} ± 0.27

AFCE (K_1%)	41.92[a] ± 3.14	59.23[b] ± 3.14	36.77[a] ± 3.14	26.58[a] ± 3.14
PER	0.53[a] ± 0.04	1.54[b] ± 0.04	0.47[a] ± 0.04	0.34[a] ± 0.04

[a, b, c,] Least square means with different superscript letters in a row are significantly different (P<0.05) D=diets

Survival Rates on Trial Diets

The survival rates (%) of *O. variabilis* (Boul.) fry fed on different trial diets showed a decrease between the first and second two weeks of experimentation. However, there was an increase in survival rates (%) from second to fifth two weeks followed by a decline in survival rates between fifth and sixth two weeks. Survival rates ranged from 64 to 100 % in all diets with substantial amount of high survival rates occurring in all treatments. Overall D2 showed high mean survival rates (91 ± 2.63%) followed by D3 (90 ± 2.12%) and D1 (88 ± 2.64%). The overall average survival rate was 89 ± 1.74% for all diets and sampling period combined. The results of ANOVA however, showed no significant difference in survival rates between different dietary treatments.

Water Quality Under Different Diet Treatments

The mean values of water temperature, pH, Dissolved oxygen and unionised ammonia in fry tanks receiving different treatments are presented in Table 6. The water quality variables recorded in the present study were within the recommended range (Ayinla, 1994). The water quality checker was not available to record the water quality variables during the sixth two weeks of experimentation.

Table 6: Water quality variables in fry tanks receiving different treatments.

Periods (weeks)	Variable	Diets			
		D1	D2	D3	D4(Control)
1	pH	$6.83^{b} \pm 0.03$	$6.81^{b} \pm 0.03$	$6.71^{a} \pm 0.03$	$6.63^{a} \pm 0.03$
	Temperature (^{o}c)	23.10 ± 0.03	23.01 ± 0.03	23.03 ± 0.03	23.11 ± 0.03
	Oxygen	$5.36^{c} \pm 0.08$	$5.10^{bc} \pm 0.08$	$4.93^{b} \pm 0.08$	$4.86^{a} \pm 0.08$
	Un ionised ammonia	$0.36^{a} \pm 0.01$	$0.35^{a} \pm 0.01$	$0.28^{b} \pm 0.01$	$0.23^{b} \pm 0.01$
2	pH	$7.04^{b} \pm 0.05$	$6.76^{a} \pm 0.05$	$6.70^{a} \pm 0.05$	$6.66^{a} \pm 0.05$
	Temperature	23.09 ± 0.15	23.08 ± 0.15	23.17 ± 0.15	23.29 ± 0.15
	Oxygen	$5.51^{b} \pm 0.20$	$5.03^{b} \pm 0.20$	$4.55^{ab} \pm 0.20$	$4.42^{a} \pm 0.20$
	Un ionised ammonia	$0.59^{a} \pm 0.01$	$0.32^{b} \pm 0.01$	$0.27^{b} \pm 0.01$	$0.24^{b} \pm 0.01$
3	pH	$6.89^{b} \pm 0.05$	$6.81^{b} \pm 0.05$	$6.67^{ab} \pm 0.05$	$6.66^{a} \pm 0.05$
	Temperature (^{o}c)	25.57 ± 1.28	22.86 ± 1.28	22 .9± 1.28	23.02 ± 1.28
	Oxygen	$5.59^{a} \pm 0.10$	$5.23^{a} \pm 0.10$	$4.85^{b} \pm 0.10$	$4.81^{c} \pm 0.10$
	Un ionised ammonia	$0.40^{a} \pm 0.01$	$0.34^{ab} \pm 0.01$	$0.24^{b} \pm 0.01$	$0.24^{b} \pm 0.01$
4	pH	6.61 ± 0.07	6.55 ± 0.07	6.63 ± 0.07	6.56 ± 0.07
	Temperature (^{o}c)	22.70 ± 1.17	22.68 ± 1.17	22.84 ± 1.17	25.11 ± 1.17
	Oxygen	$4.79^{bc} \pm 0.07$	$4.74^{b} \pm 0.07$	$4.52^{a} \pm 0.07$	$4.54^{ac} \pm 0.07$
	Un ionised ammonia	0.19 ± 0.01	0.16 ± 0.01	0.19 ± 0.01	0.17 ± 0.01
5	pH	6.82 ± 0.06	6.86 ± 0.06	6.87 ± 0.06	6.84 ± 0.06
	Temperature (^{o}c)	26.63 ± 1.74	23.29 ± 1.74	23.13 ± 1.74	23.41 ± 1.74
	Oxygen	4.78 ± 0.10	4.77 ± 0.10	4.65 ± 0.10	4.69 ± 0.10
	Un ionised ammonia	0.36 ± 0.01	0.38 ± 0.01	0.41 ± 0.01	0.37 ± 0.01

$^{a,\ b,\ c,}$ Least square means with different superscript letters in a row are significantly different ($P<0.05$), D=diets

Discussion

The feeding experiment was aimed at investigating growth performance of *O. variabilis* fry fed different diets. Protein is very important in fish growth and thus crucial ingredient in fish diets. Except for the control diet, the crude protein content of the experimental diets used in this study was within the range used elsewhere e.g., 38.9 % and 52 % (Marais *et al*., 1979; Reintz, 1984; Aneykutty *et al*., 1994; Usman *et al*., 1997). With respect to the cumulative weights and growth variables, *O. variabilis* fed on Cotton seed cakes diet showed higher performance than those fed on composite diet and Soyabean diet. However, there was no significant difference during the first and fifth two weeks of experimentation. The most likely explanation for this observation is that during the first two weeks the fry were probably still acclimatising to the tank experimental conditions and that during the fifth two weeks there occurred a fungi disease outbreak. These two factors could be responsible for the non-significant difference observed during this period.

The analysis of data showed no significant difference between cotton seed cakes diet and fishmeal control diet with respect to cumulative weights. There was no significance difference between cotton seed cakes diet and the fishmeal control diet with respect to SGR, FCR, FCE and PER except during the second sampling period. In developing countries, fishmeal, which forms the potential base for artificial feeds, is scarce and expensive (Mnembuka and Eggum, 1995). Results from the present study suggest that cotton seed cakes may be used to replace fishmeal in fish feeds due to the fact that the use of cottonseed meal in raising *O. variabilis* has shown better growth performance. Moreover cotton seed cakes are cheaper than fishmeal. Substitutions of fishmeal in fish feeds have been done for carp by Viola *et al*., (1982). Comparable to the present study, Fowler (1980) reported better growth performance and survival among chinook and coho salmon fishes fed on cottonseed diet.

The use of glandless cottonseed products in fish feeds such as *G. hirsutum* applied in the present study has shown better performance (Robinson *at al*., 1984b). Robinson *et al*. (1984b) noted that glandless cottonseed products, which contain less than 100 ppm of free gossypol, should allow for use on increased levels of cottonseed products in fish feeds. High levels of free gossypol content in glanded cottonseeds have been reported to reduce the growth of fish (Ofojeckwu and Ejike, 1984; Robinson *et al*., 1984a). The good performance of *O. variabilis* fry fed on cotton seed cakes reported in the present study may be due to the fact that gossypol in the cotton seed is rendered harmless through heat treatment during oil processing. Though the amount of gossypol content in cotton seed cake was not analysed in the present study it appears that cotton seed cake diet is an acceptable substitute for fishmeal diet in *O. variabilis*. However, lysine supplementation should not be ignored. In the present study lysine was supplemented through vitamin/mineral mix.

It is seen from the present study that *O. variabilis* fry fed on soyabean meal gave poor growth rate, AFCRs and PERs compared to those fed on cotton seed cakes and composite diets. The current results agree with the findings of other workers (Fowler, 1980; Vanketesh *et al*., 1986; Ray and Patra., 1989). Fowler (1980) reported that fish fed on diets containing heat-treated soyabeans weighed significantly less and suffered higher mortality than fed on fishmeal control diet. Fowler (1980) further noted that as the level of soyabean meal was increased and that of fishmeal decreased in the diet, growth rate was slower, regardless of degree of heat treatment. Vanketesh *et al*., (1986) reported retardation in growth of *Clarias batrachus* (Linn) and *Anabas testudiness* when fed on soyabeans. Viola *et al*., (1982) suggested lysine and methionine supplementation and oil enrichment of soyabean based diet to obtain the growth of common carp equivalent to that of fishmeal diet. However, in the present study although lysine and methionine was supplemented by vitamin/mineral mix, performance of fish fry fed on soyabean diet was poor compared with that fed on cotton seed cakes diet. Fowler, (1980) reported that supplementing soyabean meal with methionine did not significantly influence weight gain or survival in chinook and coho salmon. It is speculated that probably the heat treatment applied to soyabeans in the present study was only partial (about 100 ^{o}C) such that the enzymes that inhibit the digestion of leguminous plant protein in fish were not destroyed satisfactorily. Fowler (1980) reported low growth rate in chinook and coho salmon fed on heat-treated soybean diet with temperature range of 178 to 278 ^{o}C. But it has been recommended that, the anti-nutritional factors other than trypsin inhibitors (Wilson and Poe, 1985) contained in soybean meal may be removed by sufficient heat treatment (Spinelli *et al*., 1979). The observations reported by Fowler (1980) support the speculation that the heat applied in the present study to treat soyabeans was not sufficient enough to destroy the anti-nutritional factors. However, though soybean diet performed relatively poor than the other diets in the present study, the FCRs were relatively better than those reported by Nandeesha *et al*. (1989). The FCRs in the present study ranged from 0.85 to 2.76. Nandeesha *et al*. (1989) obtained a better growth in 'major carp', *Catla catla* (Ham.) fed on Soybean meal with FCR of 3.64. Portella *et al*. (2000) reported that artificial diets containing soybean oil promoted good growth in fingerlings. The good FCR obtained from *O. variabilis* fry fed on soyabean diet in the present study suggests that Soyabean meal containing diets can be another alternative replacement to fishmeal. However, it is recommended here that the optimum temperature for destroying the anti-nutritional factors in soyabeans without impairing other nutrients such as amino acids should be established.

Initially it was thought that the growth performance of *O. variabilis* fry fed on composite diet would probably be the best because the feed contained a mixture of nutrients from Soyabeans, Cotton seed cakes and *Azolla niloticus.* However the composite diet showed poor performance than the other diets. It is speculated that probably the incorporation of soyabean meal in the composite diet might have contributed to the poor growth performance obtained in this study. Also the presence of fibrous material in *Azolla niloticus* might have contributed to the recorded poor growth performance. of *O. variabilis* fry fed on composite diet. Almazan *et al*. (1986) showed that Nile tilapia, *O. niloticus* lost body weight when fed on fresh *Azolla* alone or sun-dried *Azolla* powder or *Azolla* pellet. The reason pointed out by Almazan *et al*. (1986) was inability of this species to deal with fibrous material, as it is a microphagous feeder. *Oreochromis* spp. including *O. variabilis* are microphagous feeders. The positive growth responses with regards to feeding *Tilapia rendalli* on *Azolla* sp in other studies (Micha *et al*., 1988) and its cheapness and abundance in supply were the basis for its choice as one of the ingredients in the trial diets in the present study.

The present study revealed significant differences in cumulative weights and growth variables not only between treatments but also between replications receiving similar treatments. This is rather surprising as substantial care was taken in controlling the experimental materials. The appearance of significant differences between replicate fry tanks implies the existence of a multitude of local factors operating in the individual fry tanks, which could not be standardized/measured. Other workers (Costa-Pierce *et al*., 1993; Mwangulumba, 1997; Lubambura, 1997) have reported similar results. Weather parameters such as air temperature and sunshine (radiation) could be among these factors and might be responsible for the differences observed between replications. Some of the fry tanks were next to windows; the windows were large and had only wire mesh, which allowed reception of sunshine radiation. Prein and Hulata (1993) argued that weather conditions might affect individual ponds differently. It is difficult to predict or regulate weather effects throughout pond management (Prein and Hulata, 1993). Costa-pierce *et al*. (1993) pointed out the existence of inherent variability in aquatic ecosystems, biological processes, individual fish growth and water quality as being responsible for the significant differences between replications receiving similar treatments. These findings emphasize the need to include an adequate number of replicates in aquatic research. In this case the effects of replications should be used as an error term of testing the main effects of treatments in the nested experiments such as in aquaculture nutrition research.

From feeding results it is seen that survival rates ranged from 63.16 % to 100 % between sampling periods. *O. variabilis* fry fed on Cotton seed cakes showed higher overall mean survival rates (90.70 ± 2.63%) followed by those fed on Soyabean meal (89.63 ± 2.12%). The results showed decline in survival rates in all diets during the first and fifth two weeks. The acclimatisation process to the experimental tank conditions may have contributed to the decline in survival rates during the first two weeks. The suspected fungal disease outbreak that occurred during the fifth two weeks of the experiments might have caused the decline in survival rates during this period. Pauly (1993) noted that disease epidemic causes reduction in survival rates in aquaculture. In the present study the fungal disease occurred but it was immediately treated by applying the fungicide.

Conclusion

From the results of the present study it is concluded that cotton seed cakes containing diet can be used as a better replacement in fishmeal in the fish feeds for feeding Tilapia, *O. variabilis*. However, Tilapia, *O. variabilis* is incapable of manipulating the fibrous material contained in *Azolla niloticus.*

recommendations

i. It is recommended that for better utilisation of the cotton seed cakes a study should be conducted to investigate the optimum level of cotton seed cake protein that would yield maximum growth and production.
ii. Since the cotton seeds lack lysine, the supplementation of this amino acids in cotton seed cake diet should be critically considered.
iii. Soyabean meal containing diet can also be used to replace fishmeal with good results. However, heat treatments for destroying the anti-nutritional factors in soyabean without impairing other nutrients like amino acids should be conducted satisfactorily.

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Aquaculture Strategy For Restoration of Threatened Lake Victoria Fishes: The case for *Oreochromis variabilis* (Boulenger, 1906) and *Labeo victorianus* (Boulenger, 1901)

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Abstract

The endemic *Oreochromis variabilis* and *L. victorianus* are among Lake Victoria's most threatened fish species whose population sizes are on the decline. This study, carried out between August 2000 and April 2001, aimed at characterizing the 'refugia' ecosystems of *O. variabilis* and its growth performance in small water bodies (SWBs), developing artificial spawning techniques and characterizing existing morphological and genetic variation of extant populations of *L. victorianus* in order to bring the species under aquaculture as a restoration strategy. Studies of *O. variabilis* were carried out by comparing its growth performance in stocked semi-intensive and modified extensive closed systems in different ecological zones within the Lake Victoria basin. Growth in *O. variabilis* evaluated as average growth rates, was satisfactory in both systems and eco-zones, even in areas with extreme environmental gradients. The isometric characteristics of *O.variabilis* estimated by formula $W = aL^b$ were better than those of wild populations in the 'refugia' ecosystems in each respective eco-zone. Multivariate analysis of morphological data showed that there was reasonable differentiation between *L. victorianus* populations from different drainages, with the southern populations being most distinct. Majority of the variation in *L. victorianus* was within populations (91.3%), with an overall F_{ST} of 0.08846 for all loci. For effective aquaculture and conservation, fish breeders should use local fish material for their stocking programs; yet ensure that different age classes form part of their brood-stock. *L. victorianus* was spawned artificially using intramuscular injection of *Clarias gariepinus* pituitary extracts (C.g.PE) and Human chorionic gonadotropin (HcG) to induce ovulation. Successful inducement of ovulation occurred only in trials with C.gPE. Fertilization rates in breeding experiments for *L. victorianus* averaged 86% and hatching percentages 70%. This study indicates the viability of the two species for culture in the basin. More hope is therefore raised for expansion on the farming practices in the basin. Such a fisheries production can provide 75% of the animal protein requirements of the poor rural households and guarantee continued survival of the species within the basin. Stocking of small water bodies for increased fish production enhances further, the integrated resource use and management of the endemic but threatened Lake Victoria fish stocks.

Key words: *Oreochromis variabilis*, *Labeo victorianus*, genetic variation, restoration, ecology, small water bodies.

Introduction

Throughout all known fisheries history, both open-access and culture fisheries, native food fishes evolve to become delicacies and part of daily diet for the resource adjacent communities. Cultivation of endemic fishes will, however, require technologies and strategies that utilise or maximise environmental productivity in order to guarantee sustainability by the often resource-poor rural human populations.

Oreochromis variabilis is presently listed in the World conservation union (IUCN) Red Book of endangered species (Maithya, 1998: Kaufman, 1992). Similarly the riverine *Labeo victorianus* (Pisces: Cyprinidae), locally known as '*ningu',* from Lake Victoria has recently experienced serious declines in population size (Whitehead, 1958; Cadwallad, 1965; Benda, 1979; Ogutu-Ohwayo, 1990). Both fish species are endemic to Lake Victoria. Their disappearance from commercial and subsistence landings of the Lake Victoria fishery has been explained by several authors as due to predation by Nile Perch (*Lates niloticus*), competition for food by Nile tilapia (*O. niloticus*) environmental degradation including pollution, over-fishing and destructive fishing methods (Cadwallad, 1965; Balirwa and Bugenyi, 1980; Ogutu-Ohwayo 1990; Greboval and Mannini 1992). This study is a concerted effort to bring the species under culture practice and restore them to the market place. While *O. variabilis* breeds easily under culture practice, the *L. victorianus* suffers a major constraint due to its inability to spawn naturally in captivity. Development of artificial spawning techniques, production of the fingerlings and their subsequent stocking in small water bodies and other larger water masses including Lake Victoria is the only opening likely to bring about their restoration.

Successful aquaculture of any fish species will depend on the existence of genetically diverse stocks since long-term adaptability of populations is dependent upon a base of genetic variation with which to respond to environmental or biotic novelties (Fisher, 1930). The use of information on morphological and life history variability, on distributions and on stock structure, enables proper utilization and management of fish during the culture period. This study aimed at characterizing the different ecosystems playing 'refugia' to *O. variabilis* and its growth performance in small water bodies (SWBs) and characterizing existing morphological and genetic diversity of extant populations of *L. victorianus* in Lake Victoria basin and to develop artificial spawning techniques in order to bring the species under aquaculture. This study was conducted between August 2000 and April 2001 after a successful reconnaissance mission.

Materials and methods

Reconnaissance studies for characterization process

For identification and selection of study sites, a 10 days' reconnaissance study was carried out in Lake Victoria and its basin from 4th to 14th August 2000. Evaluation of physical, chemical and biological integrity of water bodies was done in the field. Physical and chemical parameters were obtained by use of relevant field equipment at each sampling site before netting for fish activity started. Small water bodies were studied through observation of water mass characteristics and collection and identification of aquatic organisms. To establish the existence or otherwise of *O. variabilis* and *L. victorianus* in Lake Victoria, small water bodies and in the rivers, electro-fishing, gill netting (at least 6 hours minimum) and beach seining was done using nets of 30 mm mesh size (Knot to knot) or 30 mm code-end mesh size. The study area was within the Kenyan part of Lake Victoria basin and is shown in figure 1.

a) *Oreochromis variabilis*

Ecological studies were conducted monthly in each research site. SWBs were used as experimental plots. Sampling units were created by employing 20 x 30m stratified transects in randomized complete block design. Samples were collected monthly from September 2000 to April 2001 using gillnets of mesh sizes 30-230 mm nominal bar length. A sub-sample was randomly selected from the total sample. For each sub-sample length and weight of each individual fish were measured immediately after capture. Total length was measured to the nearest mm and total wet weight to the nearest g. The parameters *a* and *b* of the length- weight relationship ($W = aL^b$) were computed using the Least Square method (Draper and Smith, 1966) and the method of Ricker (1975) and Pauly (1984) for all sub-samples of *O. variabilis* for each water body. This enabled estimation of isometric characteristics of the populations. The sex, fecundity, maturity stage, stomach fullness and contents were determined. Size classes per capture were also determined. Environmental parameters pH, dissolved oxygen, temperature, water hardness and turbidity were measured *in situ*. The population structure and environmental gradients were then analyzed and compared with those from stocked water bodies in each eco-zone.

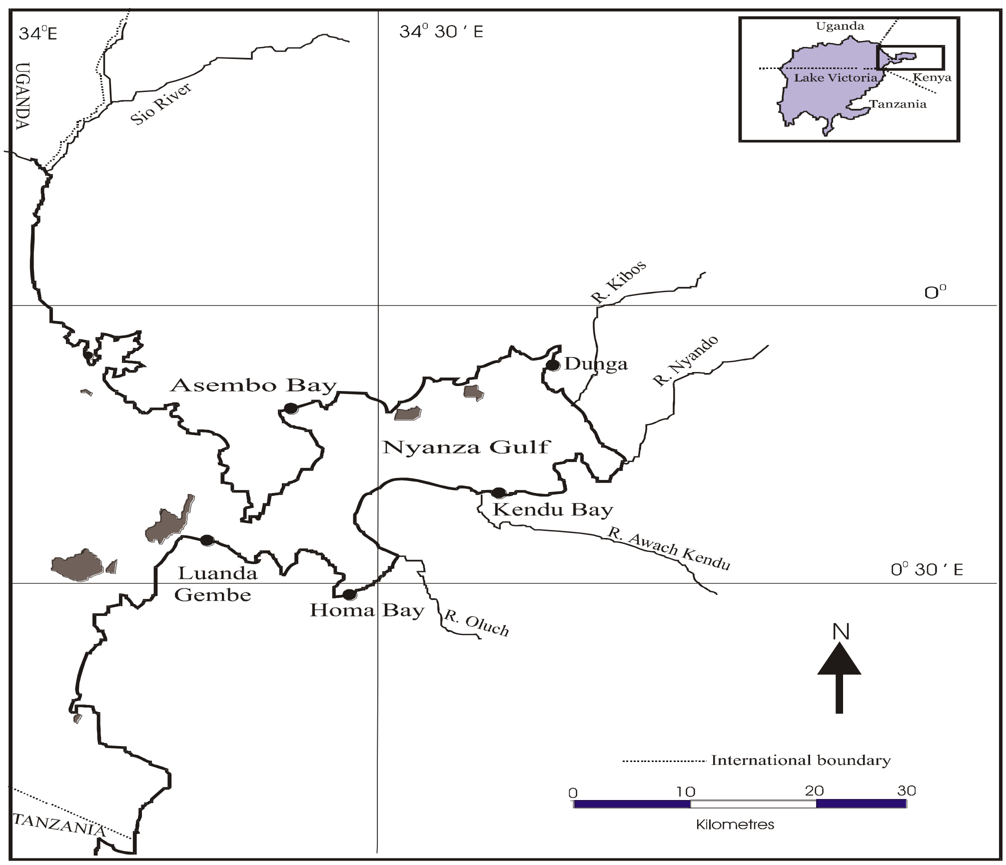

Figure 1. Map of Nyanza Gulf, Lake Victoria showing sampling sites

Fish seed for stocking ponds and SWBs were sourced from hatchery ponds at KMFRI Sangoro laboratory. Stocking of experimental plots started in October 2000 and ended in

November 2000. Fingerlings of *O. variabilis* used for stocking were 3.9 ± 1.25 SD g average weight and 4.7 ± 2.16 SD cm mean length. The experimental design was aimed at determining production levels in pond model and SWB model in terms of growth rates, condition and maximum attainable size (g) of *O. variabilis* at each recruitment size. SWB culture systems were selected on the basis of ecological zonation to represent effect of climatic regimes. Experimental stocked plots include Oki SWB, Maranda and Ochot SWBs (low altitude), Lorida Fish Farms and Suka SWB (mid altitude) and Wanyonyi Fish Farm (high altitude). Stocking densities ranged from 240 to 10,380 fingerlings to represent a rate of 1-2 fish per m^2 depending on size of the culture system. Size of experimental SWBs ranged from $900m^2$ - $16000m^2$ while experimental ponds are 150 – 600 $m^{2.}$ The stocked pond populations were fed on a starter diet (prepared according to the method of MacGrath, 1976 and Dupree, 1976) for one month while those in SWBs relied on natural productivity of the water mass. SWBs relied entirely on catchment area for fertilization and renewal of plankton growth. Ponds were fertilized with cattle dung at the rate of 3 kg and 5 kg per pond fortnightly.

To investigate the production potential of *O. variabilis* in SWBs random samples were taken from stocked SWBs through monthly harvests with replacements. Total length and wet weight of each fish individual in the samples were determined. Drag netting using mosquito mesh size nets was used for sampling the stocked plots.

a) *Labeo victorianus*

Morphological and genetic studies

L. victorianus samples for genetic studies were obtained from rivers Nzoia, Sondu-Miriu, Kuja, Yala and Nyando, which are shown in Figure 1. A total of 133 ningu samples from eight sites were chosen for this study. From each specimen, morphometric and meristic characters were recorded. These included standard length, total length, maximum body depth, head length, head width, eye diameter and number of scales on lateral line and fin ray counts on dorsal and anal fins. Fish were dissected on-site and organs transported to the laboratory in dry ice and stored at 20^0 C until analysis. Liver and muscle extracts were prepared by grinding the tissue and zymograms obtained by migration on 11% starch gels using horizontal gel electrophoresis. The following enzymes were examined: lactate dehydrogenase (LDH), aspartate aminotransferase (AAT), superoxide dismutase (SOD), alcohol dehydrogenase (ADH), esterase (EST), acid phosphatase (ACP), alkaline acid phosphatase (ALP), phosphoglucomutase (PGM), malate dehydrogenase (MDH), mannose-6-phosphate isomerase (MPI), glyceraldehyde-3-phosphate dehydrogenase (GAPDH), fructose-6-diphosphate (FDP), glycerol-3-phosphate dehydrogenase (G3PDH), creatine phosphokinase (CPK), glucose-6-phosphate isomerase (GPI), malic enzyme (ME), glucose-6-phosphate dehydrogenase (G6PDH), 6-phosphogluconate dehydrogenase (6PGDH), isocitrate dehydrogenase (IDH), glutamate dehydrogenase (GLUDH), sorbitol dehydrogenase (SDH), and catalase (CAT). Buffer systems and enzyme stain recipes followed Murphy *et al.,* (1990), Shaw and Prasad (1970), and Pasteur *et al.*, (1988) with slight modifications where necessary.

Fish from different populations differed in total length (one-way analysis of variance, $F_{7, 181}$ = 10.07, p=0.000). In morphometric studies, populations should be compared in shape variables without the effects of variation in size (Reist, 1986). The effects of size on morphometric characters such as head length, head width, eye diameter and body depth were therefore removed by calculating linear regressions for each character against standard length (Reist, 1986). The regression residuals (shape variables) were then used as response variables in a principal component analysis (PCA) and multivariate linear discriminant analysis with the software program MINITAB® for Windows (version 12.21). At first, sites were used as groups, later sites were lumped together into a northern group consisting of Yala and Nzoia, a central group consisting of Miriu, Awach and Machine and a southern group consisting of Ranen, Riana and Migori as shown in Figure 1. Grouping of sites in the northern and central groups was based on proximity to each other except for Awach and Machine, which are both tributaries of river Nyando. Tests of genetic differentiation between populations and pair-wise F_{ST} values were calculated using the internet-based program GENEPOP (Raymond and Rousset, 1995). A hierarchical analysis of molecular variation (AMOVA) was done using the Arlequin program (Schneider *et al.,* 1997), sites being grouped according to drainages and proximity to each other as done for the morphological studies above.

Breeding studies

Mature females for breeding experiments were selected by observing their abdomen. Females that had swollen and soft abdomen, fully distended ovipositors and which released eggs on applying gentle pressure on their abdomens were selected for the experiments while males were selected based on their release of white milt when gentle pressure was applied on their abdomen. Females were injected intramuscularly either once or twice with pituitary extracts of the African catfish *Clarias gariepinus* (C.g.PE) or Human chorionic gonadotropin (HcG). Controls were injected with 2 ml of normal saline. The second injection when applied was administered 12 or 13 hours later. Fish were observed for signs of ovulation after every two hours. At appropriate time eggs were stripped into dry enamel bowls and fertilized with milt pooled from three mature running males. Eggs were incubated in trays placed in cages in a slow moving (0.1 m/s) part of the river (Charo and Oirere 2000). The appropriate incubation densities were determined by recording the maximum egg diameters reached 1 hour after incubation (Table 14). These were incubated at very low densities to ensure that they had enough space for expansion. Fertilization success was determined as the percentage of eyed eggs and hatching success as the percentage of eggs that hatched.

Results and discussion

Reconnaissance study

A total of 250 dams and several ponds and rivers were visited. Major dams characterized included Ongoro, Oki, Oyombe, Kosiga, Marrum, Mukuyu, Suka Ebiruga, Winjo, Tito Kochere, Nyakisese, Komondi, Nyabuhanze, Nyansiongo, Kijauri, Emityot, Gesebei, Mamboleo, Ndubai, Kaparuso, Maranda, Ochok, Tinga- Mwer, Ulanda (Kaugage) Kalenjuok, Ochilo, Mauna, Yenga, Chwele, Marinda, Kewa, Baharini and Kesses dams. The rivers visited included Nzoia, Sondu-Miriu, Kuja, Yala, Oluch, Awach, Sio and Nyando.

A checklist of the potential food items found in the water column is presented in table 7. Most of the plankton populations found in the water column form major food items for *O. variabilis* and *L. victorianus*. This means that the propagation of the two species in SWBs (including rivers) and the main lake will require minimal supplemental feeding. Rural communities who earn their livelihood from these SWBs will require low inputs to achieve high yields. Restoration of the two species is therefore less costly after stocking with fingerlings.

Table 1 A comparison between condition of reared and wild population of *O. variabilis* in different ecozones of Lake Victoria basin and refugia ecosystem of the lake.

Stock Type	Ecozone/Aquazone/L. Refugium	Condition (b coefficient)
Reared	Low altitude	2.71 - 2.91
wild		2.27 - 3.54
Reared	Mid altitude	2.32 - 3.38
wild		2.12 - 3.80
Reared	High altitude	2.14 - 2.75
wild		2.22 - 3.15
Reared	Lake refugia	-
wild		2.10 - 3.78

Table 2 Growth rates after one month of stocking

Experimental plot	Eco-zone	Growth rate (g/day)
Wanyonyi unit	High altitude	0.43
Suka unit	Mid altitude	0.51
Lorida units		0.54
Maranda and Ochok units	Low altitude	0.65
Oki unit		0.78

Ecological studies in refugia systems showed that males of *O. variabilis* were found to be more numerous than females with sex ratio of 4:1 respectively. Sex ratios in *L. victorianus* differed within different river systems with generally more males than females. Average sex ratio was 3:2 (males to females respectively). First maturity in males occurred at 14.2 cm average length while size of first brooding females ranged from 15.1 - 19.0 cm with fecundity range of 51 to 4294. Length at first maturity for *L. victorianus* averaged 7.3 cm for females and 7.9 cm for males while fecundity ranged from 20,712 to 65, 955. Shallow and rocky inshore areas where primary productivity was very high provided major refugia habitats for *O. variabilis* in Lake Victoria while *L. victorianus* occurred mainly in rocky and stony parts of the rivers with periphytonic algae where they foraged.

Table 3 Growth rates after four months of stocking

Experimental plot	**Ecozone**	**Growth rate (g/d)**
Wanyonyi unit	High altitude	0.33
Suka unit	Mid altitude	0.48
Lorida units		0.33
Maranda and Ochok units	Low altitude	0.50
Oki unit		0.63

Growth studies on *Oreochromis variabilis*

Differential trends in length and weight were determined by comparing the condition of stocked and wild populations in the refugia ecosystems in the three aquazones. The results are shown in Table 1. It is observed that there is better isometric condition in the stocked than the wild populations in the low and middle altitude of Lake Victoria catchment. The condition of the stocked population is also better than that of the lake refugia population (Table 1) *O. variabilis* tends to assume allometric growth condition as the catchment altitude increases. The condition is significantly higher in low and mild altitude than in higher altitude (P=0.05). Tables 2 and 3 show growth rates in two-month stepwise analysis between period of stocking and last period of evaluation. These growth rates were used as the principal determinants of differential trends in growth patterns due to effect of aquazonation. Overwhelming evidence indicate that lower altitude stocked populations attained higher growth rates (g/day) than those in mid and higher altitude. The difference between growth rates in mid and higher altitude is not significant (t=44.083; p=0.05).

Environmental gradients driving the ecozonations are shown in Table 5. It is shown that temperature and dissolved oxygen are limiting environmental gradients in aquazones and fish growth. Table 6 shows the phytoplankton food of *O. variablilis*. It has been demonstrated that this fish species feeds on a great variety of food plankton. *Anabaena* *spp*, diatoms and green algae are more common food items in all ecological regions. Aquaculture zonation as demonstrated in this study is necessary for describing the interplay between environments, species and system choice. This is in conformity with West (1996) who reports that the degree of success in achieving full potential is determined by the prevailing ecological conditions.

Table 4. A comparison between population of stocked and wild populations of *O. variabilis*

ECOZONE	EXPERIMENTAL PLOT	STOCK TYPE	RECRUITED SIZE CLASS (CM)	ATTAINED AVERAGE WET WEIGHT (g) ± SD
Low altitude	Oki farm	Stocked	10.0-15	42.7 ± 13.08
			15.1-20.0	72.5 ± 30.19
	Oele beach	Wild	10.0-15.0	54.45 ± 11.88
			15.1-20.0	94.8 ± 9.83
	Yenga dam	Wild	10.0-15.0	46.67 ± 10.37
			15.1-20.1	99.17 ± 25.71
Medium altitude	Suka farm	Stocked	10.0-15.0	51.36 ± 14.17
			15.1-20.0	89.17 ± 32.14
	Komondi dam	Wild	10.0-15.0	55 ± 14.91
			15.1-20.0	121 ± 20.61
High altitude	Wanyonyi farm	Stocked	10.0-15.0	38.95 ± 20.24
			15.1-20.0	-
	Wabukhonyi dam	Wild	10.0-15.0	43 ± 11.69
			15.1-20	85 ± 26.14

Labeo victorianus

(i) **Morphological and genetic variation**

The principal component analysis resulted in four components with eigen values of more than 1.00. The first three components explained over 50% of all morphological variation (Table 8). The first principal component (PC1) was composed of body depth and eye diameter, the second principal component (PC2) was composed of head length, head width and weight while the third component (PC3) consisted of number of rays on dorsal and anal fins. PC4 consisted of number of scales on lateral line. However, analysis of variation of the regression residuals was non-significant: body depth, eye diameter ($F_{7,159}$=0.00, P= 1.000), head length, head width ($F_{7,159}$=0.01, P= 1.000), and weight ($F_{7,159}$=0.002, P=1.000). The discriminant analyses of morphological data results are shown for populations and groups in Table 9 and 10 respectively. In the between population analysis, the classification accuracy of the discriminant function was low with the proportion of correctly assigned individuals ranging from between 0% for Yala and Miriu to 55% for Ranen with a mean of 21.9% for the entire sample. The within group classification was low for populations in the central group (19.1%) and for the northern group (38.2%) but was relatively high (67.2%) for the southern group, with a mean of 40.6% for the three groups.

Table 5 Characterization of major environmental gradients influencing growth and population characteristics of *O. variabilis* in Lake Victoria catchment

Ecozone	**Environmental**	**Gradient**
Low altitude	Temperature	26-30.6^{0}c
	Dissolved oxygen	6.5-9.8mg/l
	PH	6.92-8.8
	Water hardness	50.1-130mg/l $CaCO_3$
	Turbidity	72.9-375.0 NTU
Middle altitude	Temperature	20.1-26.8^{0}c
	Dissolved oxygen	5.1-7.6mg/l
	PH	5.0-7.8
	Water hardness	40.0-86mg/l $CaCO_3$
	Turbidity	53.2-188.7NTU
High altitude	Temperature	18.5-24.9^{0}c
	Dissolved oxygen	4.2-7.2mg/l
	PH	5.4-7.4
	Water hardness	75.0-256mg/l $CaCO_3$
	Turbidity	69.7-367NTU
Lake Victoria refugia systems	Temperature	27.5-30.7^{0}c
	Dissolved oxygen	5.3-7.2mg/l
	PH	7.4-8.3
	Water hardness	86.0-92.3 mg/l $CaC0_3$
	Turbidity	69.4-100.8NTU

Studies on species of *Labeo* have shown that there is considerable overlap in meristic and morphological variables across species (Reid, 1985). For example *Labeo umbratus* and *L. capensis* from two localities (Van Vuuren *et al*., 1990), showed a great deal of overlap in body shape variables within and between both species. This overlap in characters was also evident in this study. Nevertheless, body depth; eye diameter and head parameters could explain most of the morphological variation. Although body depth may reflect fecundity in female fish, there was no significant variation in fish from different populations and therefore the observed value in the PCA reflects true morphological variation. In Africa and Asia, species of *Labeo* that live in swift waters have characteristic features, which include small eyes (Reid, 1985). Thus observed eye diameter differences may be more reflective of environmental rather than genetic differences although according to Reid (1985), small eyes do not confer any immediate hydrodynamic advantages. Head morphology reflects the feeding habits of a fish species (Pakkasmaa and Piironen, 2001), and may indicate subtle differences in diet of fish from

Table 6: Phytoplanktonic food of *O. variabilis*

Ecozone/Ecosystem	***Commonly identified food item***
Lake refugia	**Aulacosira**
	Microcystis sp
	Melosira
	Anabaena
	Oscillatoria
	Scenedesmus
Low altitude	*Ankistrodesmus*
	Euglena
	Microcystis
	Anabaena
	Oscillatoria
	Nitzschia
	Discoid diatoms
Mid altitude	Diatoms
	Oscillatoria
	Chlorococcus
	Euglena
	Anabaena
	Scenedesmus
High altitude	*Anabaena*
	Oscillatoria
	Euglenoid flagellates
	Selanastrum

different sites. So far, studies on the feeding habits of *L. victorianus* have indicated that its diet consists of algae and detritus material (Cadwallad, 1965, Ochumba and Manyala, 1992); but since no attempt has been made to identify the algal species involved, it is now impossible to relate different populations to particular diets, although such a relationship is likely. To answer this question, further study on foraging behavior and diet may be necessary.

In the investigation of allozyme variation, 12 enzymes coding for 26 presumptive loci could be scored (Table 11). Of these, 8 were found to be polymorphic and their allele frequencies are presented in Table 12. A hierarchical analysis of molecular variance (AMOVA) in which sites were grouped into the three groups: southern, central and northern, indicated that 91.15% of the total genetic variability was due to variation within sites with an overall F_{ST} of 0.08846 for all loci. A matrix comparison of genetic and morphological distances showed a positive but non-significant correlation (r = 0.334, P = 0.089).

ii) **Artificial breeding of *Labeo victorianus***

Successful inducement of ovulation occurred in all trials involving the use of C.g.PE but did not occur in the case of HcG or in the controls. In C.g.PE, it took a total of 20 hours for the fish to completely ovulate. The amount of hormones administered, weight of fish, fertilization and hatching percentages are presented in Table 13. Fertilization rates ranged from 75-95%, which are acceptable considering that some of the males may have been unripe since they were not treated with hormones.

Hatching began at 39 hours after fertilization with live embryos occurring only where two injections of C.g.PE were administered. This time after hatch (39 hours) is consistent with hatching times for *Labeo umbratus* as reported by Bok (1987) but conflicts with Fryer and Whitehead (1959) who reported a time of first hatch of 45 hours after fertilization. The water temperature during incubation was 21.8 to 23.6°C. Temperature range for experiments by Fryer and Whitehead (1959), who incubated *L. victorianus* eggs collected from the wild in irrigated troughs, was between 23 and 25°C, which is higher than the present study. Since temperature under normal circumstances reduces first time of hatch, it is necessary that specific experiments be done to understand the effect of temperature on hatching times of *L. victorianus* eggs.

The hatching percentages of eggs incubated in river water ranged from 50 to 90% with an average of 70%. These were more consistently high when compared with findings by other studies on egg incubation of cyprinids. For example Mills (1980) found 0% hatching rates when he incubated Dace, *Leuciscus leuciscus* eggs in river water probably due to siltation but got an average of 94% hatching successes in re- circulated spring water. Although ovulation occurred in females injected once with C.g.PE, none of the eggs hatched successfully. A number of eggs developed to the stage where optical vesicles and notochord appeared but did not elongate even though they hatched after 48 hours. The second injection appears to be necessary for hatching of live fully formed fry.

Egg diameters before induction of ovulation, and one hour after treatment are shown in table 14. It has been suggested that a single layer of eggs with little egg contact is ideal for hatching. The number of eggs that can fit into an incubation tray should be calculated based on the maximum diameter of the eggs one hour after incubation because by this time the eggs will have reached their maximum diameters. Based on the egg diameters the best incubation diameters are approximately 3.5 mm^2/egg i.e. to incubate 100 eggs on a tray will require at least 18.7 x 18.7 mm space. Higher egg densities during incubation

Table 7. Checklist of common phytoplankton found in the small water bodies

Species name	
Anabaena circinalis	*Microcoleus subtorulosus*
Anabaena flos-aquae	*Microcystis aeruginosa*
Anabaena spiroides	*Microcystis marginata*
Ankistrodesmus falcatus	*Microcystis viridis*
Aphaizomenon flos-aquae	*Nitzchia holsatica*
Asterionella formesa	*Nitzchia sigmoidea*
Asterionella gracillina	*Nostoc kihlmani*
Bacillus	*Nostoc linckia*
Beggiatoa sp.	*Oscillatoria tenuis*
Bulbochaeta intermedia	*Oscilltoria putrida*
Chodatella armata	*Peritriches*
Chromatium okenii	*Phacus caudatus*
Cylindrospermum stagnale	*Phacus pleuronectes*
Cymbella caespitosa	*Plectonema tomasiniamana*
Cymbella cistula	*Pseudomonas hylina*
Epithemia turgida	*Rivularia sp.*
Euglena oxyuris	*Siderocapsa major*
Euglena tripteris	*Siderocapsa treubii*
Flagilaria crotonensis	*Sideromonas confervarum*
Fragilaria constuens	*Sphacrotilus natans*
Gallionella ferruginea	*Spirillum granulatum*
Gloeocapsa turgida	*Surirella biseriata*
Gloeotila contorta	*Synedra actinastriodes*
Lamprocystis rosea-persicina	*Synedra acus*
Lamprosystis roseo-persicina	*Thiobacillus thioparus*
Leptothrix crassa	*Thiocystis violacea*
Leptothrix ochracea	*Thiodictyon elegans*
Leptothrix sideropous	*Thiopedia rosea*
Lyngbya nyassae	*Thiophysa macrophysa*
Melosira ambiqua	*Tolypothrix lanata*
Melosira italica	*Trachelomonas rugulosa*
Merismopedia glauca	*Uroglena volvox*
Merismopedia tenuissima	*Zoogloea ramigera*

appear to have a negative effect on the realized hatching successes by reduction of aeration and accelerated fungal attacks.

Table 8. Principal Component analysis for all the variables

Variable *	PC1	PC2	PC3	PC4
Maximum body depth	**-0.668**	-0.134	0.090	-0.068
Head length	0.156	**-0.511**	0.362	-0.264
Head width	0.116	**-0.544**	0.424	0.060
Eye diameter	**-0.669**	-0.111	0.134	-0.104
Weight	0.100	**-0.427**	-0.159	0.575
Scales on lateral line	-0.215	0.069	0.062	**0.739**
Rays on dorsal fin	0.108	0.244	**0.541**	0.171
Rays on anal fin	0.027	0.406	**0.585**	0.074
Eigenvalue	2.050	1.432	1.085	1.044
% variance	25.6	17.9	13.6	13.0
Cumulative % variance	25.6	43.5	57.1	70.1

*Analysis for the size dependent variables is based on the correlation matrix. A total of eight Principal Components were computed, the components shown here are those with eigenvalues higher than 1. The largest correlation coefficients for each variable are in bold

The use of common carp pituitary (CPE) and Human chorionic gonadotropin (HcG) to induce ovulation in cyprinids, although successful, has several drawbacks (Lin and Peter, 1991). These drawbacks include their high costs and for HcG, the problems of storage. In our case, HcG could not induce ovulation even after increasing the hormonal strength to 5000 iu and may be useful only after solving the problem of dosage. The use of pituitary gland from locally available and more abundant fish like *C. gariepinus* is much more cost effective and can effectively replace CPE. C.g.PE could be developed into an important source for hormone for *L. victorianus* and other related cyprinids in the region just as is the case for common carp pituitary extracts.

The hatched *L. victorianus* fry have shown very high survival rates of up to 70% in the first 80 days post-hatch being fed solely on phytoplankton. Given its high fecundity of up to 162,000 and its high growth rate (Cadwallad 1965, Fryer and Whitehead 1959), ningu like all other *Labeos* is likely to do well under aquaculture conditions. The role of captive breeding in the conservation and aquaculture of this species is crucial. Since *in situ* breeding programmes that do not remove fish from their natural environment are more desirable than those that introduce un-natural sources of physical stress (Vrijenhoek, 1998), the successful *in situ* trials give an appropriate option for carrying out restocking programmes.

Table 9. Discriminant analysis showing proportion of individuals correctly assigned to each population. Average proportion for individuals correctly assigned for the entire sample is in bold.

Population	Awach	Machine	Miriu	Migori	Ranen	Riana	Nzoia	Yala
Awach	6	4	8	3	4	6	1	3
Machine	1	10	7	3	4	4	2	4
Miriu	0	0	0	0	0	0	0	0
Migori	0	0	0	1	0	0	0	2
Ranen	3	7	6	6	11	7	3	7
Riana	0	0	1	0	0	1	0	1
Nzoia	4	5	6	1	1	6	6	5
Yala	0	0	0	0	0	0	0	0
Total	14	26	28	14	20	24	12	22
Correct	6	10	0	1	11	1	6	0
Proportion	0.429	0.385	0.000	0.071	0.550	0.042	0.500	0.000
Total correct proportion	**21.9%**							

The results of this study indicated low genetic differentiation among different drainages yet showed an appreciable amount of morphological variation *in L. victorianus*, which could be used as a basis for management and aquaculture. The genetic structure observed, although weak, implies that for successful breeding and conservation, fish breeders should use local fish material for their stocking programs, yet ensure that different age classes form part of their brood stock. This study has shown that more studies involving other molecular techniques, a larger and more widespread samples collected over several years are advisable. Furthermore there is reason to carry out comparative growth studies on fish from the three morphologically distinct groups to investigate if this distinctiveness may be genetic.

The potential of small water bodies as restoration sites

Potential for small-scale fisheries and for restoration of *O. variabilis* and *L. victorianus* in and around SWBs in the Lake Victoria basin is greatly unrecognised and undervalued. SWBs could provide over 75% of the animal protein requirements of the rural households (Nasser, 1999). It is therefore important that these water bodies are well stocked and their fisheries managed and that developmental activities explicitly consider their impact on the overall inland fisheries. This is a little studied fishery resource, which could contribute significantly to the fishery of Kenya's inland waters. The number of species of plankton realised from these water bodies is a clear indication that small water bodies can be useful production units for the two species. The higher growth condition values observed in the smaller water bodies may suggest that they have comparatively higher primary productivity that can support a higher biomass of *O. variabilis.*

Table 10. Discriminant analysis showing proportion of individuals correctly assigned to each group. Average proportion for individuals correctly assigned for the three groups are in bold.

Group	Central	Southern	Northern
Central	13	11	8
Southern	33	39	13
Northern	22	8	13
Total (n)	68	58	34
N correct	13	39	13
Proportion	0.191	0.672	0.382
Total correct proportion	**40.6%**		

Table 11. Enzymes that had sufficient activity, their enzyme commission numbers, tissue they were stained from and the buffer, which gave clearest resolution. In the tissue column, L refers to liver and M refers to muscle. Buffers: TCE (Tris citrate EDTA. Electrode/gel pH 7), Tris HCl-(electrode pH 8.2/ gel pH 8.5), RW(Tri-lithium-citrate borate- electrode pH:8.1/ gel pH 8.3).

Protein	Locus	E.C. No.	Tissue	Buffer
Esterase	EST	3.1.1.1	L	Tris HCl
Glyceraldehyde-3-phosphate	GAPDH	1.2.1.12	M	TCE
dehydrogenase	LDH	1.1.1.27	M	Tris HCl
Lactate dehydrogenase	GLUDH	1.4.1.2	L/M	RW
Glutamate dehydrogenase	G3PDH	1.1.1.8	L/M	RW
Glycerol-3-phosphate dehydrogenase	ADH	1.1.1.1	L	RW
Alcohol dehydrogenase	GPI	5.3.1.9	L/M	RW
Glucose-6-phosphate isomerase	PGM	5.4.2.2.	L/M	Tris HCl
Phosphoglucomutase	ME	1.1.1.40	M	RW
Malic enzyme	MDH	1.1.1.37	M	RW
Malate dehydrogenase	G6PDH	1.1.1.49	L/M	RW
Glucose-6-phosphate dehydrogenase	ACP	3.1.3.2	M	RW
Acid phosphatase				

Conclusion

SWBs in Kenya are numerous and an under - utilized resource for fish production. Culture of indigenous food fishes such as *O. variabilis* in these ecosystems can play an important role in improving the food and nutrition security of rural population. The most appropriate and available techniques to achieve full aquaculture potential should include species introductions and stockings into small water bodies and new

Table 12. Allele frequencies for polymorphic loci across 8 sites in five rivers in Lake Victoria basin.

Northern open lake				**Nyanza Gulf**			**River Kuja**		
Site		Awach(1)	Machine (2)	Miriu (3)	Migori (4)	Ranen (5)	Riana (6)	Nzoia (7)	Yala (8)
n		14	26	28	14	20	24	12	22
	Allele								
GAPDH-2	100	0.893	0.942	0.857	0.929	0.611	0.938	0.917	1.000
	90	0.107	0.058	0.143	0.071	0.389	0.062	0.083	0.000
MDH-1	110	0.357	0.750	0.796	0.214	0.775	0.604	0.792	0.864
	100	0.643	0.250	0.204	0.786	0.225	0.396	0.208	0.136
LDH-1	100	0.857	0.904	0.750	0.964	0.825	0.875	0.750	0.659
	90	0.143	0.096	0.250	0.036	0.175	0.125	0.250	0.341
EST-1	100	0.857	0.769	0.679	0.929	0.700	0.771	0.833	0.786
	95	0.143	0.231	0.321	0.071	0.300	0.229	0.167	0.214
EST-2	100	0.286	0.077	0.232	0.179	0.375	0.326	0.125	0.300
	95	0.714	0.827	0.768	0.821	0.625	0.674	0.875	0.675
	90	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.025
GPI-2	110	0.714	0.846	1.000	0.857	0.950	0.667	0.667	0.659
	100	0.286	0.154	0.000	0.143	0.050	0.333	0.333	0.341
PGM-1	105	0.643	0.404	1.000	1.000	0.425	0.750	1.000	0.614
	100	0.143	0.385	0.000	0.000	0.225	0.250	0.000	0.227
	95	0.214	0.212	0.000	0.000	0.350	0.000	0.000	0.159
ADH	100	0.607	0.615	0.714	0.964	0.650	0.833	0.458	0.477
	85	0.393	0.385	0 .286	0.036	0.350	0.167	0.542	0.523
Ho		0.091	0.102	0.087	0.059	0.091	0.092	0.105	0.099
He		0.129	0.119	0.126	0.065	0.144	0.093	0.104	0.148

Number beside site name refers to the sites as indicated on figure 1., n = number of individuals sampled at each site; Ho = observed heterozygosity.

impoundments. Economically viable aquaculture production however, is dependent on the equilibrium between environment quality and choice of culture system. Using *Oreochromis variabilis* as the test species SWBs in the Lake Victoria basin have proved viable extensive culture systems.

Growth performance of stocked *O. variabilis* in semi-intensive and modified extensive closed systems in different ecological zones within the Lake Victoria basin was satisfactory in both systems, even in areas with extreme environmental gradients. This indicates the viability of the species for culture in the basin. The successful artificial breeding of *L. victorianus* together with the acquired information on genetic and morphological variation is an important step towards the achievement of sustainable utilization and management of the species. The fact that *L. victorianus* and *O. variabilis* are both herbivores and the high primary productivity of the small water bodies shows that there is little requirement for supplemental feeding if these water bodies are fertilized. More hope is therefore raised for expansion on the farming practices in the basin. The small water bodies can be transformed into extensive culture systems with fingerlings of *O. variabilis* and *L. victorianus* being stocked into SWBs to support a diversified inland fisheries production. Such a fisheries production can provide 75% of the animal protein requirements of

Table13. Hormonal treatment applied, fertilization rates and hatching percentages in ningu eggs incubated in river water.

	Hormonal application		Fertilization rates (%)	Hatching success (%)
	Treatment 1 (6.30 p.m.)	Treatment 1 (7.00a.m)		
Group 1	C.g.PE,	C.g.PE,	86	70
Group 2	C.g.PE, 1.8mg	-	80	0
Group 3	Hcg	HcG	0	0
Group 4	HcG	-	-	-
Group 5	Saline (controls)	Saline	-	-

Table 14. Egg sizes of *Labeo victorianus* at different stages of induced ovulation and incubation.

	Egg diameters			
	Before induction	After 1st treatment	After 2nd treatment	1hour after incubation
Mean egg size	0.67	0.67	0.68	1.85
Std deviation	0.05	0.05	0.04	0.37
Minimum size	0.6	0.62	0.64	1.2
Maximum size	0.7	0.7	0.72	2.4

the resource-poor rural households as well as well as guaranteeing continued survival of the species. Since “necessity is the mother of invention,” the innovative evolutionary progression in aquaculture should have more emphasis on diversification of farming practices. Man-made impoundments for water storage for domestic, irrigation, industrial and livestock uses are rapidly becoming a more commonplace feature in Kenya. Stocking of these water bodies for increased fish production of threatened and endangered fish species enhances further the integrated resource use and management of the Lake Victoria ecosystem.

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Comparative study of hatching rates of African catfish (*Clarias gariepinus* Burchell 1822) eggs on different substrates.

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Abstract

The choice of incubation substrate materials is one of the major factors to consider in the production of African catfish (*Clarias gariepinus*) fingerlings. There was significant difference between the hatching rates of the catfish eggs incubated on natural substrates: Nile cabbage (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), pond weed (*Ceratophyllum dermasum*) roots, and green grass leaves (*Commelina Sp*.) and the artificial substrates: sisal (*Agava sp.*), plastic, papyrus (*Cyperus papyrus*), kakaban mats and concrete slabs. Ranking of the natural substrates by performance indicated that *Pistia* roots were the best with mean hatching rate of 66.2 ± 3.62%, the green grass leaves were second with a mean of 54.0 ± 3.46%, water hyacinth roots were third with mean rate of 49.7 ± 3.16%, while the *Ceratophyllum* roots were fourth with a mean of 13.0 ± 2.37%. The ranks for the artificial substrate showed that the concrete slabs tied with the sisal mats as the highest having mean rates of 18.6 ± 2.8% and 18.6 ± 2.0% respectively, papyrus was second with a mean rate of 12.2 ± 1.2%, kakaban was third with a mean rate of 11.8 ± 1.9% while the plastic mats were the last with mean rate of 4.0 ± 0.7%. The natural substrates performed better than the artificial substrate. The best performing natural substrates were those with floating ability and thin fibrous roots that seemed to allow higher aeration of the eggs during incubation. There were minimal costs incurred in the usage of the natural substrates.

Introduction

The fish of the family Clariidae is endemic to Africa. *Clarias gariepinus* currently but mistakenly, synonymized with *C. mossambicus, C. lazeras* and *C. senegalensis* ranges from Natal and the orange River in South Africa through central, west east and north Africa where it is under culture (Teugels, 1986). The widespread distribution is a reflection of their ability to tolerate a wide range of environmental parameters. *C. gariepinus* adapt well to artificial environments, and has rapidly gained status as premier aquaculture species Hetch, Uys and Britz (1988). Early in the twentieth century, colonists realized that *Clarias* might have an economic value since they were highly prized by the locals and catches demanded high market prices. By the early 1950's Belgian workers started *Clarias* culturing techniques in the former Belgian Congo.

Clarias species are noted to have a rapid growth, a high reproductive potential and sturdy resistance to environmental variations. *Clarias* has been bred in the South and central Africa with varying degree of success (Clay, 1977; Msiska, 1981; and Hogendoorn, 1990). The potential for culture of *Clarias* is enormous. It comes at a time when tilapias have given discouraging results due to their uncontrolled breeding, diluted genetic progeny and stunted growth. A reliable supply of good quality fry resulting from high fecundity as well as good natality is an essential prerequisite to aquaculture development in Kenya. The Government of Kenya, Fisheries Department (1998) report show that the culture of *Clarias gariepinus* is still low as indicated by production data over the years. In the years 1995 to 1998 the total aquaculture production was 14 metric tones and *C. gariepinus* contributed only 2% of this. In comparison, tilapia production accounted for 45% over the same period. Maithya, *et al.,* (2000) pointed out the great potentials of aquaculture in Kenya while Owiti, (2000) emphasized the need to reactivate aquaculture in Kenya. The issue of the catfish low production can be tackled by addressing the factors limiting aquaculture development including the main problem of seed production.

Demand for *C. gariepinus* fingerlings in Kenya both in aquaculture and as baits in capture fisheries have substantially increased in the last few years. The Fisheries Department estimates that for aquaculture activities, there is a demand of about 10 million *C. gariepinus* fingerlings per year, while the demand *for C. gariepinus* in the Lake Victoria capture fisheries is about 18 million fingerlings per year. This brings to a total of about 28 million *C. gariepinus* fingerlings per year, Government of Kenya (1998).

The government supplies about 5 million fingerlings per year through the Fisheries Department and the Lake Basin Development Authority (LBDA) farms. This leaves an estimated deficit of about 23 million fingerlings. There is therefore a need to increase their supply. This is only possible through ‘simple-and- easy-to-adopt’ protocols on efficient seed production and management for small-scale fish farmers.

The African catfish naturally spawns in floodplains during wet season in response to the rise in water levels (Pillay, 1990). Seed collection from the wild is however unreliable and limited only to rainy seasons. Under culture conditions, ovulation of the species can be induced by environmental manipulation and/or hormonal stimulation.

Presently, catfish seed production in Kenya has had limited success due to the high mortality of eggs and larvae. This has been attributed to among other factors, the use of unsuitable incubation substrates, e.g., mud, sand or concrete surfaces are commonly used despite the poor results. The hatching rates are usually as low as 25% (Obuya *et al.,* 1995), which is, far much below the 50-70 % recorded in well-managed hatcheries in other countries (de Graaf *et al.,* 1995). Moreover, there still is a poor survival rate of eggs and larvae to the fingerling stage, mainly as a result of inadequate nutrition during the early nursing phases along with careless nursery management practices. Successful hatching of fish eggs and careful feeding of larvae during the early stages of their development is essential for better larvae survival. This experiment aimed at realizing simple and low cost management practices for mass production of *Clarias* fingerlings.

Materials and Methods

This study was carried out at Kibos Fish Farm in Kisumu District, Nyanza Province. The farm is located along the Kisumu – Miwani road about 10 km from Kisumu Town. Mature brood stocks (females of about 300g to 500g and males of over 200g) were collected from the wild in Kano plains and stocked in Chwele, Yala and Kibos Fish

Farms, all which are within the Lake Victoria Basin. They were then transferred from the farms and stocked at Kibos in a pond of about 300 m^2.

A few sample of the brood stock were sacrificed to obtain pituitary glands. The pituitaries were pulverized in a porcelain mortar, mixed with a physiological solution (9 g of de-iodised sodium chloride in one litre of distilled water), to make a pituitary suspension. The suspension was then injected intra-muscularly into the dorsal muscle of the experimental female fish, as outlined in de Graaf *et al.* (1996). Randomly selected, ready to spawn, females were used.

Eggs were obtained by stripping the females while milt was obtained by sacrificing the males. One male was used to fertilize eggs from three females. The milt was diluted with the physiological solution and was added to the stripped eggs, which were fertilized by adding equal volume of clean water to activate the sperms (de Graaf *et al.*,1995). A bird's feather was used to spread the eggs evenly on the substrate in bunches of 600-1200 eggs.

The eggs were then incubated on different substrate materials; *kakabans*, sisal, papyrus and plastic (nylon) mats all with equal surface area of 1350 cm^2. These were put in flow-through concrete troughs. Concrete slabs were used as control due to the prevalent use of concretes in the region. The same set up was done for the other set of substrates i.e., root fibres of Nile cabbage (*Pistia stratiotes)*, water hyacinth (*Eichhornia crassipes*), pond weed (*Ceratophyllum dermasum*) roots, and green grass (*Commelina Sp*.) leaves. The DO, PH, conductivity and temperature were monitored on a daily basis. The percentage hatching was obtained by using the formula outlined below,

$$\textit{Hatching rate} = \frac{\textit{No. of live hatchlings}}{\textit{No. of incubated eggs}} \times 100$$

as stipulated in Viveen *et al.*, (1985). Costs of using each of the hatching practices were assessed by accounting for all expenses incurred in each method. Completely Randomized Block Design (CRBD) was used to allocate 600-1200 eggs into each of the experimental units.

Statistical analysis

The results of hatching rates were analysed by two-way analysis of variance (ANOVA). Multiple comparison analysis was used to assess any heterogeneity. Multiple Range Tests in Stat graphics Version 2.1 (Statistical Graphics Corporation 1994, Maryland, USA) that was based on the Fisher's least significance procedure as described by Zar (1984) was used to discriminate among means and offered more than two rankings. The tests were at 95% significance level, ($p<0.05$).

For each of the substrates data, a two-way ANOVA was carried out to assess for differences among the replicates. The two-way ANOVA was carried out to assess for differences between the hatching rates of eggs from the different female spawners.

The samples were pooled to represent only the substrates data classification. The resulting data was subjected to a one-way ANOVA.

Results

The experiments were carried out in the same environment with similar ambient conditions (Table 1).

Table 1: The mean parameters values

Parameter	**Mean value**	**Unit**
Dissolved Oxygen (DO)	5.9±0.2	Mg\l
Temperature	22.9±1.1	^{o}C
PH	7.0±0.5	No
Conductivity	649.2± 10.2	µS

Artificial substrates

From the analyses of the data, it can be noted that there was a statistically significant difference in the means of the hatching rates of all the artificial test substrates. The mean percentage rates of hatching ranged from 0.0 to 9.0 for plastic, 2.0 to 21.0 for kakaban, 5.0 to 9.0 for papyrus, 0.0 to 28.0 for sisal mats and from 0.0 to 31.0 for concrete slab (Table 2). The general hatching rates of the eggs on this category of the substrates was low with the highest being 31.0 for the concrete slab (control). The mean rates were 4.0, 11.8, 12.2, 18.6 and 18.6 for plastic, kakaban, papyrus, sisal mats and concrete slabs respectively. There was a statistically significant difference between the means of the four data samples at 95.0% confidence level.

Multiple range tests based on the Fisher's least significance difference procedure as described by Zar, (1984) was used to discriminate among the means. The tests revealed that all the means were statistically different from each other. However two pairs, the concrete and sisal and that of kakaban and papyrus, distinctively portrayed insignificant differences. Three homogenous groups of means were identified while ranking the substrates performance.

The plastic performed below 8% and was ranked lowest, the kakaban and papyrus performed between 8% and 16% while the sisal and concrete performed between 15 % and 25 % and was ranked highest as can be seen in Table 2.

Multiple range tests based on the Fisher's least significance difference procedure as described by Zar, (1984) was used to discriminate among the means. The tests revealed that all the means were statistically different from each other. However two pairs, the concrete and sisal and that of kakaban and papyrus, distinctively portrayed insignificant differences. Three homogenous groups of means were identified while ranking the substrates performance.

Table 2: The percentage hatching rates of artificial test substrates.

Substrate number	Sisal	Plastic	Kakaban	Papyrus	Concrete
1	15	6	21	13	25
2	14	1	9	17	21
3	27	5	16	17	31
4	0	0	16	6	3
5	7	1	5	5	0
6	2	0	19	5	1
7	25	2	10	12	10
8	20	3	13	10	12
9	15	4	12	7	17
10	20	5	2	15	9
11	18	2	4	11	14
12	17	2	11	9	16
13	15	2	10	8	17
14	17	6	12	11	22
15	22	3	20	10	26
16	24	5	2	12	20
17	25	1	10	13	29
18	17	2	14	16	30
19	24	7	5	18	25
20	20	3	12	15	24
21	25	2	10	12	10
22	27	5	16	18	31
23	17	6	15	12	15
24	21	5	16	10	19
25	19	3	6	13	16
26	22	7	16	14	21
27	21	5	6	14	17
28	22	7	4	13	16
29	28	6	17	19	31
30	18	8	21	15	28
31	16	5	13	9	19
32	17	9	15	12	22

The plastic performed below 8% and was ranked lowest, the kakaban and papyrus performed between 8% and 16% while the sisal and concrete performed between 15 % and 25 % and was ranked highest as can be seen in Table 2.

Natural substrates

The rates of hatching on the natural substrates ranged from 33.0% to 82.0% for *Pistia*, 0.0% to 33.0% for *C. dermasum* (pond weed), 34.0% to 74.0% for the green grass leaves (*Commelina Sp*.), and from 28.0% to 68.0% for the *E. crassipes* (water hyacinth) roots. The general hatching rates of the eggs on this category of the substrates was noted to be significantly high with the highest being 82% for the *Pistia* roots (Table 3).

The mean rates were 66.2%, 13.0%, 54.0%, and 49.7% for *Pistia*, *C. dermasum*, green grass leaves (*Commelina Sp*.) and the *E. crassipes* roots respectively. The p-value of the F-test was less than 0.05 and therefore there was a statistically significant difference between the means of the four data samples at 95.0% confidence level.

The multiple range tests revealed that all the means were significantly different from each other except for one pair, the green grass leaves and water hyacinth roots which portrayed an insignificant difference. Three homogenous groups of means were identified with *C. dermasum* performing between 15% and 18%, the green grass leaves (*Commelina Sp.*) and *E. crassipes* roots rates falling between 43% and 60% while the *Pistia* rates ranking the highest at between 62% and 76%.

From the on going, it can be noted that the artificial substrates performed very poorly compared to the natural substrates. The best of the natural substrates were the *pistia* roots. The hatching rates from the *C. dermasum* substrate were quite low, this was thought to be due to the fast decaying and settling to the bottom characteristics of the substrate. Other substrates performed better probably because of their free-floating ability hence allowing better aeration of the eggs.

The costs of the substrates

There was significant cost difference incurred during the use of the artificial substrates and that of the natural substrates. The costs of using the artificial substrate was higher than that of the natural ones as can be seen in Tables 4 and 5. The costs in the use of artificial materials were more of direct in contrast with the indirect costs in the use of the natural materials. The indirect costs emanated from the opportunity costs for doing other activities or the man-hours used while collecting the substrate materials.

Table 3: The percentage (%) hatching rates of natural test substrates

Substrate number	Water cabbage	Pond weed	Grass	Water hyacinth
1	45	33	51	52
2	33	5	36	39
3	70	16	38	47
4	53	0	57	68
5	49	1	37	28
6	71	1	35	41
7	64	16	50	50
8	48	19	57	49
9	57	11	37	37
10	62	18	58	49
11	70	15	71	41
12	75	10	57	46
13	81	11	45	51
14	60	10	74	58
15	72	9	66	44
16	68	10	62	51
17	75	13	60	43
18	79	11	58	55
19	72	9	52	48
20	75	22	58	50
21	80	15	34	49
22	71	16	54	50
23	63	11	45	42
24	76	19	59	65
25	72	9	60	52
26	73	12	73	68
27	81	19	54	63
28	74	13	67	65
29	70	11	58	49
30	49	19	57	48
31	63	18	59	42
32	65	16	50	50

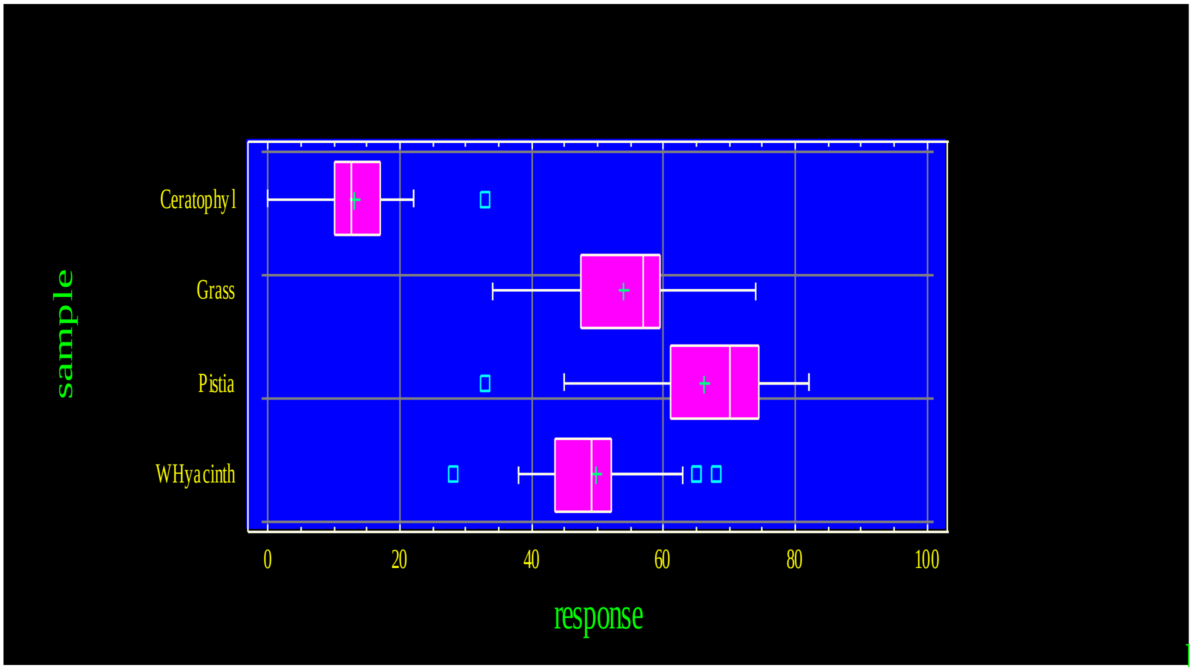

Figure 1. The percentage ranking of performance of the natural substrates.

Table 4: Costs of the artificial substrates

Substrate material	Surface area	Costs (Kshs)
Kakaban mat	1350 cm^2	10
Sisal mat	1350 cm^2	8
Plastic mat	1350 cm^2	10
Concrete slab	1350 cm^2	20

Table 5: Costs of the natural substrate

Substrate material	Number of fibrous strands/leaves	Costs (Kshs)
Water cabbage	200	2
Water hyacinth	200	2
Pondweed	200	2
Grass	200	1

Discussion

The *Clarias gariepinus* hatching protocols practiced in the experiments described above are easy to apply by small-scale fish farmers. They are particularly appropriate in the rural areas where there is no electricity and where most of the small-scale farmers are based. The costs are also minimal hence not a burden to the farmers the majority of whom are very poor.

This experiment showed that the hatching rates of the natural substrates especially those of the *Pistia* whose average hatching rate ranged between 62% and 76% were quite high when compared to the 25% hatching rates in Western Kenya as indicated by Obuya *et al.,* (1995).

The fecundity of *C. gariepinus* is high, using the Hogendoorn (1980) method of estimating fecundity, *Total no. of eggs = 66.6 x female body weight (g)* the estimated fecundity of the local catfish ranged from 15,000 to 50,000 eggs. Based on the small-scale fish farming levels in Kenya where most farmers have 1- 5 ponds of 50 m^2 each, a farmer using only one female to address his annual catfish seeds requirements may have an over supply if he uses the appropriate hatching and nursing procedures.

Fertilized eggs are usually incubated in stagnant or running water. A general principle of egg incubation is that water is renewed in order to provide oxygen and that after hatching the larvae are separated from the remaining egg-shells and dead eggs. This is important in order to avoid fungal infection of the hatchlings and consequent larval mortalities. Several incubation techniques have been used as outlined by de Graaf, (1996). One method is whereby the eggs are spread out on the bottom of a concrete basin. This method works well but it has the disadvantages that dead eggs and eggshells are not separated from the hatchlings.

The eggs can also be spread out on a screen (mesh size 1 mm), which is then placed on the bottom of a concrete basin. This method works well as the hatchlings will pass through the screen and the dead eggs and shell remain on the screen. By removing the screen from the basin, separation of the hatchling and the dead eggs is readily achieved.
Our experiments show that the eggs can be allowed to stick to the roots of floating substrates such as water hyacinth (*Eichhornia crassipes*), Nile cabbage or water lettuce (*Pistia stratiotes*), or any other such as the green grass leaves that floats inside a concrete basin or hapa. The cost of the natural substrates are low and the hatchlings are easily separated from the dead eggs as long as the distance between the roots of the plants and the hapa bottom is kept at between 15-20 cm. The fertilized eggs usually develop normally if the incubation conditions mainly the oxygen, temperature and cleanness are provided.
In actual practice, there is always some mortally. We believe that the hatching rates are usually low due to low dissolved oxygen level and high turbidity of the water brought about by the use of a particular incubation substrate. Moreover, collection techniques of the hatchlings from the ponds or the large concrete tank beds increase mortality due to stress, is time consuming and laborious. Hence, low cost hatching protocols that can be practiced with ease by farmers in simple rural based hatcheries need to be developed.

The use of screened substrates, or fibrous materials placed in small holding container units may enhance oxygenation of eggs during incubation and make collection of hatchlings easier, faster and less stressing resulting to lower mortality rates.
According to Pillay (1990), about 3-5 % of the eggs die a few hours after incubation and another 5-10 % die near completion of development or during hatching. Higher mortalities are not normal and can be caused by several factors including a prolonged latency period, high stressing of female spawners during latency period, incubation of more than one layer of eggs per incubation substrate, poor incubation conditions or high concentration of fungicide. We believe that the hatching rates have hitherto been low due to low dissolved oxygen and high turbidity of the water that brought about by the use of a particular substrate. Moreover, collection techniques of the hatchling contribute greatly to the survival of the hatchlings. Less stressing techniques will have higher survival rates

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The feeding habits and development of digestive system of *Labeo victorianus* Blgr (pisces: cyprinidae)

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Abstract

The goal of the current research effort is to revive through aquaculture, the population of *Labeo victorianus* ("Ningu"), a previously important commercial fish species of Lake Victoria but now threatened with extinction. The specific focus of the study was to obtain sufficient understanding of the feeding biology and adaptations of *L. victorianus* to changes in diet during growth to enable development of diets for commercial aquaculture production.

Specimens of "Ningu" were collected from the mouths of Rivers Kagera and Sio on monthly basis for an entire annual cycle. The composition of the gut contents were analysed to determine the feeding habits. The structure of the digestive system was studied to determine the adaptations of the system to its diet. Ripe broodstocks collected from the mouth of River Sio during peak spawning were successfully induced to spawn in station ponds at Kajjansi using a hormone and incubated in pond and tanks to hatch. The process of weaning from the yolk food reserve (endogenous feeding) to external (exogenous) feeding, the starter (weaning) diet and the development process of the digestive system were recorded.

Results so far show that the adult "Ningu" is an omnivore predominantly feeding on detritus material consisting mainly of plant material. The digestive system has no stomach and consists of an extremely elongated gut with intestinal length ranging from 7 to 11.8 times the body length. This is typical of predominantly herbivorous animals. Spawning of fish induced at 5.00 pm occurred overnight at temperatures of 19-20 ^{o}C. Hatching of eggs started after 10 hours and lasted up to 18 hours at the above temperatures. The yolk sac food reserve lasted from five to six days before the larvae were able to take in external food. The development of the digestive system, including the liver, pancreas and the secretary and absorptive epithelia, was sufficiently advanced by day four to enable the larvae to start external feeding. Weaning to exogenous (external) food source started on the fifth day after hatching. Zooplankton, especially rotifers, were found to be the most suitable starter diet and then the larvae gradually shifted from a predominantly animal diet towards a predominantly plant diet as it grew. The larvae of "Ningu" were unable to utilize plant diet until they were two weeks old. The larvae were able to take in and utilise dry diet from three weeks and a formulation of Maize bran (40%), "mukene" 33%), baby soya food (25%) and mineral premixes (2%) gave reasonable survival and growth.

The quick development of the swim bladder and the pectoral fin after one and two days, respectively, was found to be very important for survival of the larvae, facilitating escape from predators and searching for food.

Key words: Induced spawning, yolk sac, endogenous feeding, exogenous feeding, weaning

Introduction

Fish catches from the major lakes in the East African Region are on the decline and a number of indigenous fish species are threatened with extinction (Uganda Fisheries Department Annual reports, 1988; Ogutu-Ohwayo, 1990a, 1990b; Ogutu-Ohwayo and Okaronon, 1996). Among the previously most popular indigenous species of Lake Victoria that are now referred to as endangered (LVEMP, 1997) is *Labeo victorianus*, locally known as "Ningu" in East Africa. The "Ningu" had been described by Cadwalladr, (1965, 1969) as a commercially important migratory fish of Lake Victoria and also one of the most abundant fish landed. From the 1950's, however, the number of fish landed dropped significantly and by the mid 1960’s *Labeo victorianus* had virtually disappeared in the catches as shown in Figure 1 (Cadwalladr, 1965, 1969). The “Ningu” is exploited during rains when sexually mature fish collect at river mouths on their migration route to spawning grounds. Owing to the exploitation at this stage in its life history, there began a decline in “Ningu” population, especially as the less efficient traditional methods of reed traps were replaced by the more efficient gill-net methods during the 1930’s and 1940’s (Cadwalladr, 1965).

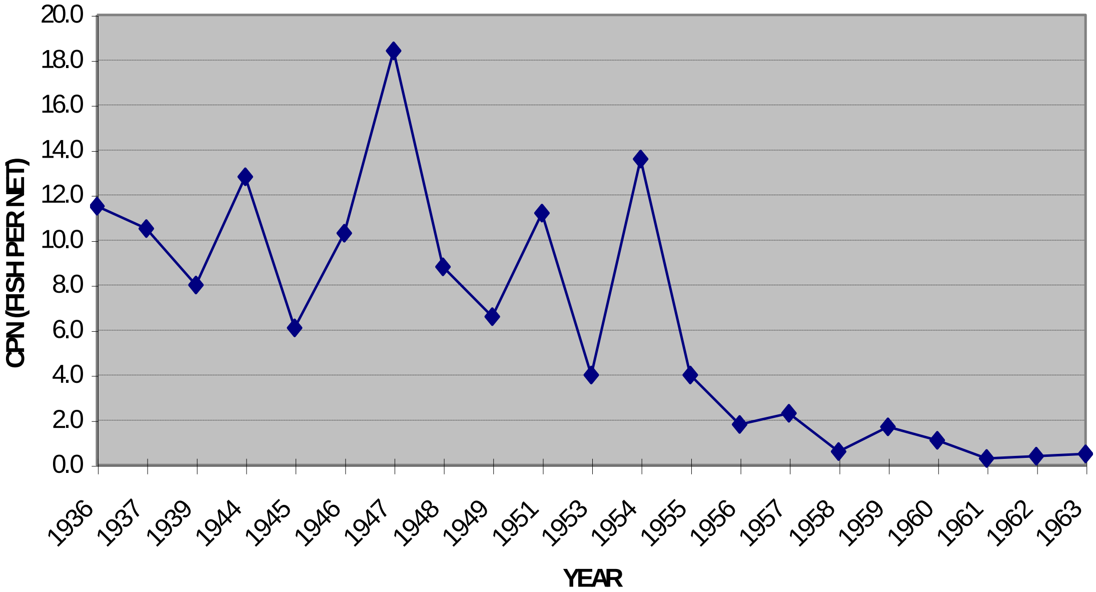

Figure 1. Annual catch records of *Labeo victorianus* for River Kagera. Source: Cadwalladr (1965)

In its effort to revive the populations of endangered fish species indigenous to Lake Victoria, the Lake Victoria Environmental Management Project (LVEMP) selected *Labeo victorianus* among the top priority species for revival (LVEMP, 1997).

The goal of the present research effort is to revive the population of “Ningu” through commercial aquaculture production. The two most important pre-requisites for domesticating any animal are being able to **breed** and to **feed** the animal in captivity (De Saliva and Anderson, 1995). In turn, a full understanding of the feeding habits and the adaptations to these habits is crucial to development of quality feed for that animal (De Saliva and Anderson, 1995).

Objective

The objective of the study is to understand the feeding biology of “Ningu” in order to be able to develop appropriate feeds for the different developmental stages of the fish. The specific objectives were:

i. To understand the digestive system of “Ningu”
ii. To determine the feeding habit of “Ningu”,
iii. To determine the earliest time to start feeding, “Ningu” larvae,
iv. To determine the most suitable starter diet that gives best growth and survival and the earliest time the “Ningu” is able to utilise dry formulated feed.

v. To determine the development of the digestive systems and the adaptations of “Ningu” to the feeds for the different developmental stages

Significance of the study

i) *Labeo victorianus* is a very popular fish that fetches high market price. Its commercial production in ponds will be a very profitable enterprise.
ii) The natural stocks of *Labeo victorianus* have been threatened. Commercial production of the fish in ponds could be a way of reviving the population and/or ease pressure on natural stocks.
iii) Details of the nutritional requirements for the different developmental stages of “Ningu” and adaptations to different diets that would enable development of these diets are not known.
iv) There are many other Cyprinids similar to “Ningu” with equally high aquaculture potential which could benefit from the knowledge acquired in the study of development of food for *Labeo victorianus.* This could give useful clues to development of other indigenous Cyprinids with potential for aquaculture, such as *Barbus* spp.

Materials and methods

Shallow (up to 20 m deep) inshore areas of Lake Victoria around the mouths of Rivers Sio and Kagera were randomly sampled and interviews with fishermen conducted to identify sampling areas. *Labeo victorianus* lives in the shallow inshore waters 0-20 m deep from where ripe adults migrate into rivers to spawn during rains (Greenwood, 1965; Cadwalladr, 1965, 1969; Kudhongania and Cordone, 1974).

Fish samples were collected every month for a complete annual cycle from the mouths and along Rivers Kagera and Sio. Fishing was done using gill nets of assorted mesh sizes of 1½”, 2”, 2 ½” and 3” mounted by the 50% and operated by drifting along the rivers. Other samples were also purchased from fishermen, when catches were very low. Each individual fish was weighed and measured then cut open to remove the viscera and other organs before weighing again. Parameters including sex, maturity stage, total weight, fork and standard lengths, weight of gut, weight of mesenteric fat, weight of gonad and the weight of the gutted fish were recorded. The entire gastro-intestinal tract (GIT) for each fish was preserved in Bouin’s solution and secured in sample bottles for laboratory analysis.

Some fish not so badly hurt by the gear were transported in 500 litre water tanks under aeration and stocked in station ponds at Kajjansi for breeding trials. The lengths of straightened GIT were measured and the morphology and anatomy of the entire GIT from lip to the anal opening were studied after histological processing and staining using standard histological methods.

The contents were stripped onto a watch glass, blotted dry and weighed to the nearest 0.01g. The contents of the first part of the gut were emptied onto petri dishes, isolated into major food categories and quantified using the subjective technique modified from Pillay, (1952), which gives volumes occupied by each food category as percentage of total volume.

Three pairs of ripe broodstocks, collected from R. Sio at the peak of spawning season in April, 2001 and held in Kajjansi Station ponds for three days to acclimate, were induced to spawn at 5.00 pm on 18 April, 2001. Aquaspawn hormone was administered by intra-muscular injection around the mid dorsal region at a rate of 0.5 ml/kg of fish and the fish put in 1 x 2 x 0.5 m nylon "happa" lined with curtain liner material with mesh sizes about 0.2 mm to hold the fry. Spawning occurred overnight. Some eggs were left in the "happa" in the pond and others transferred into fibre glass nursing tanks placed on the veranda. For both systems, water temperature, pH, ammonia and dissolved oxygen were recorded at six hourly intervals. Hatching started at around 11.00 am and lasted over 18 hours. The larvae were inspected under the microscope daily to determine when the yolk food reserve was exhausted and when external feeding could be started. The first larvae with food in the gut were seen on the fifth day after hatching. From that time the fry were fed on water of predominantly zooplankton culture.

Two weeks prior to inducing spawning two sets of culture systems for the live food for the expected fry were set up. One consisted of compost of rotting vegetation and dry chicken manure in 1,000-litre asbestos tanks and another one was in ponds enriched with soaked sunflower cake at 10 kg/100 m^3 of water. A plankton community rich in zooplankton (mainly rotifers) and some phytoplankton developed after two weeks. Water samples from these systems were collected and fed to the larvae in the various nursing systems. Samples of the larvae were collected on daily basis and fixed in Bouin's solution for study of development of the digestive system.

Weaning from endogenous feeding (on yolk reserve) to exogenous feeding started on the fifth day from hatching. Three sets of experiment were set up in triplicate in glass aquaria to determine whether phytoplankton or zooplankton or a combination of both as starter food gave the best growth and survival of the larvae of "Ningu". One set had zooplankton only, predominantly rotifers. The second set had phytoplankton only, algae of mixed species; and the third set contained mixtures of zooplankton and phytoplankton in about equal portions (about half the concentration as in set 1 and 2 above). Each of these 10-litre tanks were stocked with 40 fry of "Ningu" with predetermined total lengths. The tanks were adequately aerated, stocks of the respective food items replenished every two days and water was replaced every two weeks. Initially the total lengths of individual fish were measured to the nearest mm, later individual weights of fish larvae were taken to nearest 0.001 g, and the number surviving was counted every month for three months.

Another set of experiments was run to determine at what size the fry of "Ningu" started taking in dry formulated feed. Two different sizes; the 3 week old (7.2 mm) and the 5 week old (12.3 mm TL); juveniles were stocked at about 40 fish per 5 litre aquaria which was filled with fresh water from a spring well. A formulation of dry diet that had been commonly used at the Station to feed fish consisting of maize bran 43%, *Rastrineobola argentea* ("mukene") 30 %, Baby soya 25% and mineral/vitamin premix 2% was fed to the "Ningu" fry at 10% body weight fed in morning and in the afternoon. The feed was ground fine and sieved through a 200 µm mesh to allow the fry with its small mouth take it. The water was adequately aerated and replaced once every week. The total length of the fish (initially) and its weight (later) were recorded individually and the number of the fish surviving was recorded each month for four months. Later on proximate analysis of the formulated diet was done to determine the amount of protein, lipid, energy and minerals it contained. Later fresh tissue of the juvenile fish was analysed to get the composition of protein, lipids, energy and mineral. This composition gives an approximation of the dietary requirements of the fish to which the formulated diet should be matched (De Saliva and Anderson, 1995).

In Asia one of the best growths of the Asian Cyprinids is obtained from ponds treated with vegetable oils (Gregory, pers. comm, 2001). A set of trials with a local vegetable oil was set up to try and maintain growth of “Ningu” in ponds to allow further observations on the development of the digestive system. Two 100 m^2 ponds were drained to eliminate any other fish from the pond and necessary repairs made the pond. The ponds were limed with 25 kg of builder’s white lime spread at the pond bottom to raise the pH. The ponds were then flooded with fresh water passed through fine screens to prevent entry of wild fish. Sunflower cake, (2 kg per 100 m^2 pond) was soaked overnight to form a slurry and sprinkled throughout the ponds. This treatment was repeated every week. Fish samples were removed every month for study of the development of the digestive system. Opportunity was also taken to monitor performance of “Ningu” in sunflower cake-treated ponds by recording the weights and total lengths of individual fish in the samples each month.

Results

The mouth of “Ningu” is ventrally positioned and has soft and retractable lips bearing soft teeth-like barbs with soft-toothed pads. There is no evidence of pharyngeal teeth in “Ningu” but the buccal cavity has a hard pad on the upper palate. The oesophagus is a short (1 cm) muscular tube whose epithelium contains goblet cells for mucous secretion to lubricate food during swallowing. There was no evidence of digestion in the oesophagus. “Ningu” has no stomach. The oesophagus leads to a relatively large intestinal bulb about a quarter the length of the intestine, which then tapers to a relatively smaller intestinal tract, ending at the anal pore. The intestine of the adult “Ningu” is extremely long, ranging from 7 to 11.8 times the fork length of the fish as shown in Table 1 and Figure 3. Over 90% of the intestinal length is coiled into several concentric circles to fit the belly of the fish.

The gut content of “Ningu” was dominated by detritus (40%) consisting mainly of plant parts followed by algae (30%). Insect and insect parts, zooplankton (mainly rotifers) and unidentifiable materials occurred in almost equal parts (10% each). The results are shown in Table 2 and Figure 2 below.

Table 1. The gut length of *Labeo victorianus* and other fish species in relation to feeding habit (extracted from De Saliva and Anderson, 1986)

Species	Feeding habit	RGL[NinguGreenwood] MIN	RGL MAX
Ptychocheilis oreganensis (Rich.)	Carnivorous	0.78	0.78
Chela hacaila (Ham.)	Carnivorous	0.88	0.88
Barilius moorei (Blgr.)	Carnivorous	0.65	0.8
Elopichthys bambusa (Rich.)	Carnivorous	0.63	0.63
Erythraculta erythropterus (Bas.)	Carnivorous, insects	0.77	1.5
Chelethiops elogatus (Blgr.)	Zooplankton	0.75	0.75
Engraulicypris minutus (Blgr.)	Zooplankton	0.7	0.7
Leptocypris modestus (Blgr.)	Invertebrates	0.8	1
Rostrogobio amurensis (Tar.)	Invertebrates	0.8	1.4
Barbus ticto (Gunth.)	Invertebrates, plants	1.58	1.58
B. tor (Ham.)	Invertebrates, plants	1.24	1.24
B. sharpeyi (Gunth.)	Plants	2.79	3.18
Amblypharyngodon mola (Ham.)	Plants	2.8	2.8
*Ctenopharyngodon idella** (Val.)	Plants	2.5	2.5
Ladislavia taczanowski (Dyb.)	Algae, invertebrates	2	2.5
Garra dembensis (Rupp.)	Algae, invertebrates	4.5	4.5
*Catla catla** (Ham.)	Periphyton, plants, insect larvae	4.68	4.68
Varicorhinus herratensis (Keys)	Algae, detritus	6	7.5
*Hypophthalmicthys molitrix** (Val.)	Phytoplankton	13	13
*Cirrhina mrigala** (Ham.)	Algae, detritus	8	8
Labeo calbasu (Ham.)	Plants, weeds, algae, diatoms	3.75	10.33
L. limeatus (Blagr.)	Algae, detritus	16.1	16.1
L. horie (Cuv.)	Algae, detritus	15.5	15.5
L. victorianus, adult		7	11.08
L. victorianus, juveniles		0.67	2.94

1 RGL = Relative gut length (gut length divided by total length of the fish)

Table 2. The composition of the gut content of "Ningu".

Food category	**Percentage**
Detrital materials	40%
Algae	30%
Insecta	10%
Rotifers	10%
Others (Unidentified)	10%
Total	**100%**

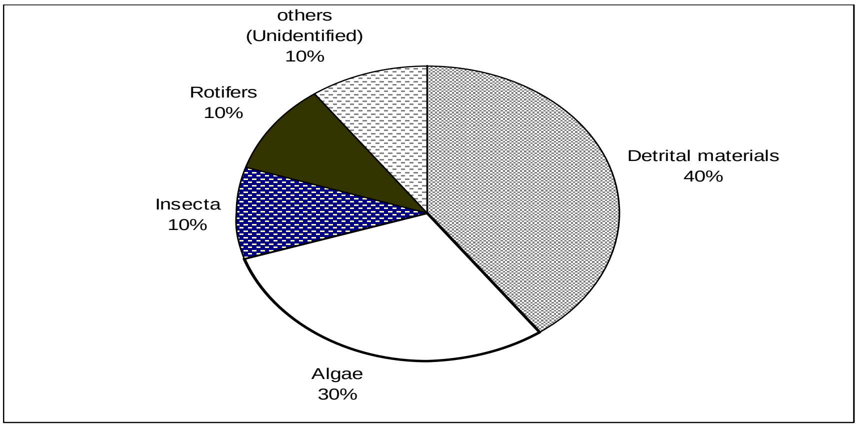

Figure 2. The composition of the gut content of *Labeo victorianus* from Kagera River.

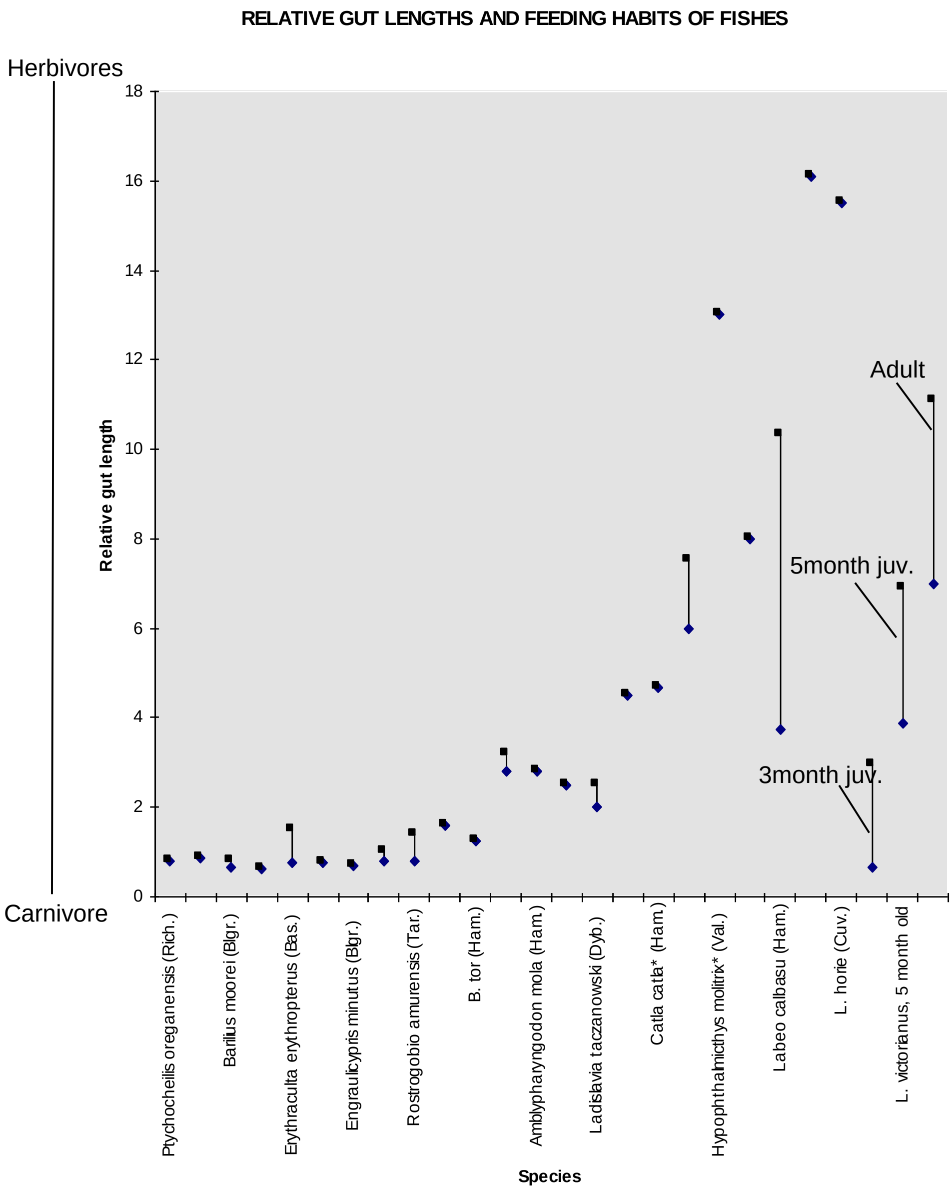

Figure 3. Relative gut length in relation to feeding habits for various fish species, including "Ningu".

Results of the analysis of relative gut fullness (RGW) determined by the formula (weight of gut/weight of gutted fish) and relative mesenteric fat content (RFW) determined by (weight of mesenteric fat/weight of gutted fish) during an entire annual cycle indicated a clear seasonal feeding cycle in "Ningu". Both these parameters reached peaks around the months of April and October and minima between these peaks for both the male and female fish. These periods coincide with the spawning seasons and the minima coincide with the end of spawning season (Figures 4 and 5). The peak of RFW is slightly ahead of the peaks for the RGW.

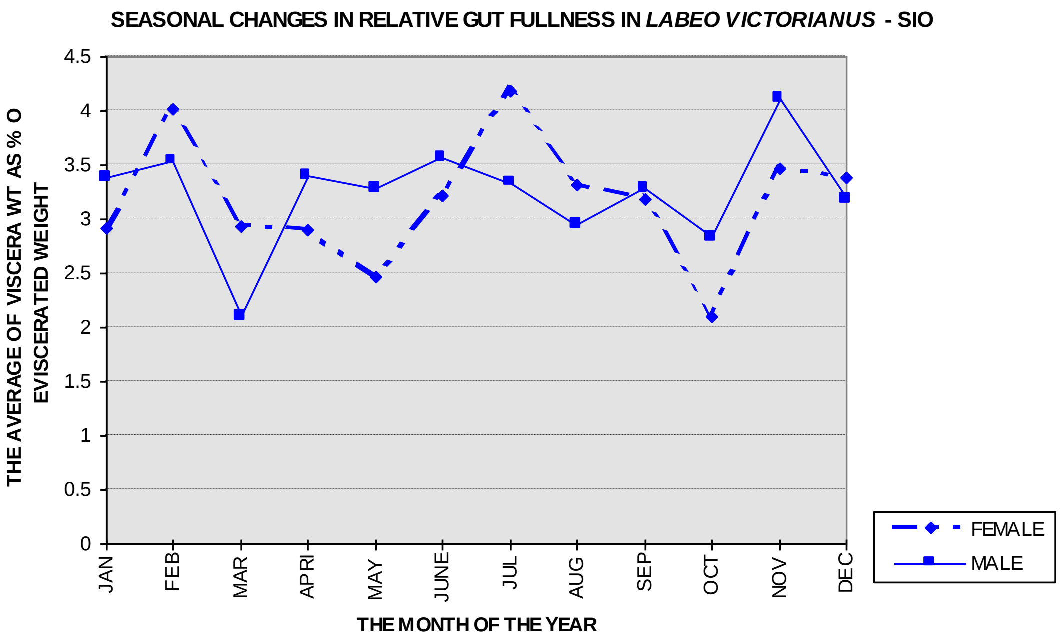

Figure 4. Seasonal changes in relative gut fullness in *Labeo victorianus* of R. Sio

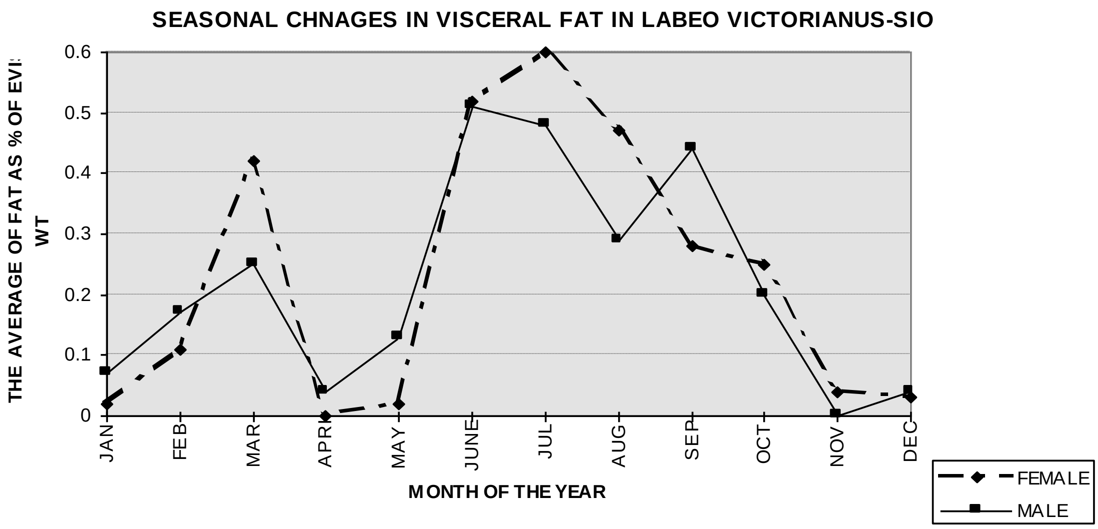

Figure 5. Seasonal changes in mesenteric fat in *Labeo victorianus* of River Sio River.

The “Ningu” depended on yolk sac food reserve for five to six days while the digestive system was developing for external feeding. External food in the gut of “ningu” was first detected on the fifth day .

Animal diet as starter food resulted in the best growth and survival for “Ningu” fry over either the plant diet alone or a combination of both plant and animal diet as shown in Figures 6 and 7.

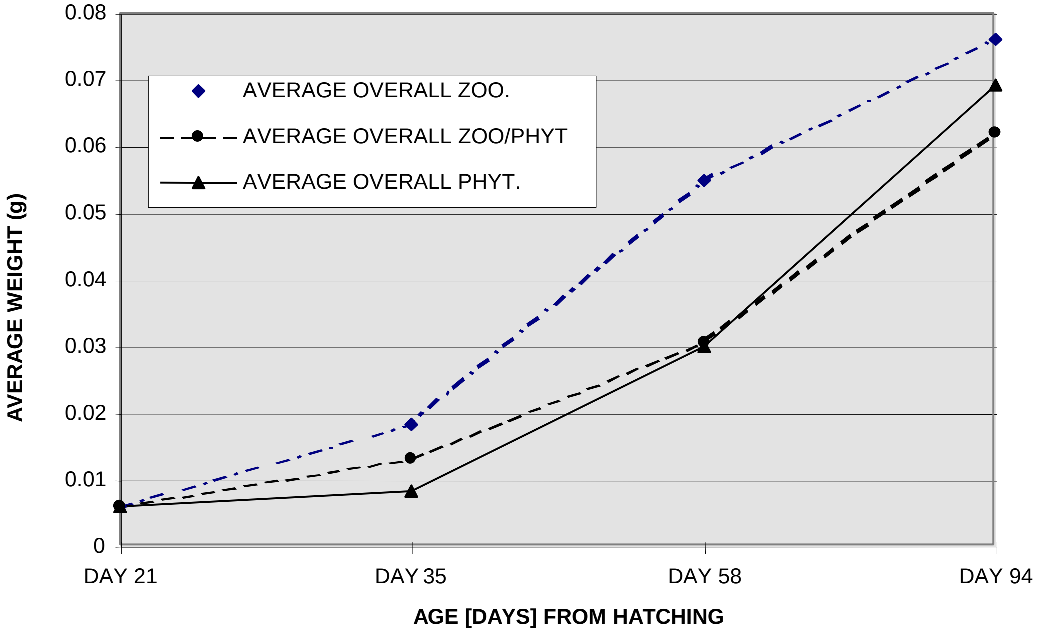

Figure 6. Impact of phytoplankton and zooplankton as starter diet on growth of *Labeo victorianus*

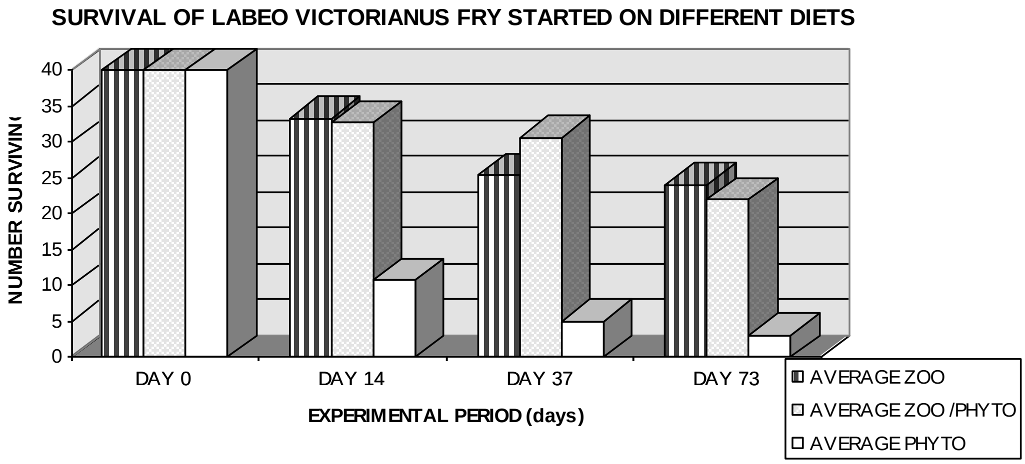

Figure 7. The impact of different starter diets on survival of juvenile “Ningu”

Both the three-week- (7.2 mm TL) and five-week-old (12.3 mm TL) juveniles were able to survive and grow on dry diet, as shown in Figure 8. The smaller juveniles, however, suffered a higher mortality in the initial stage than the larger ones (Figure 9).

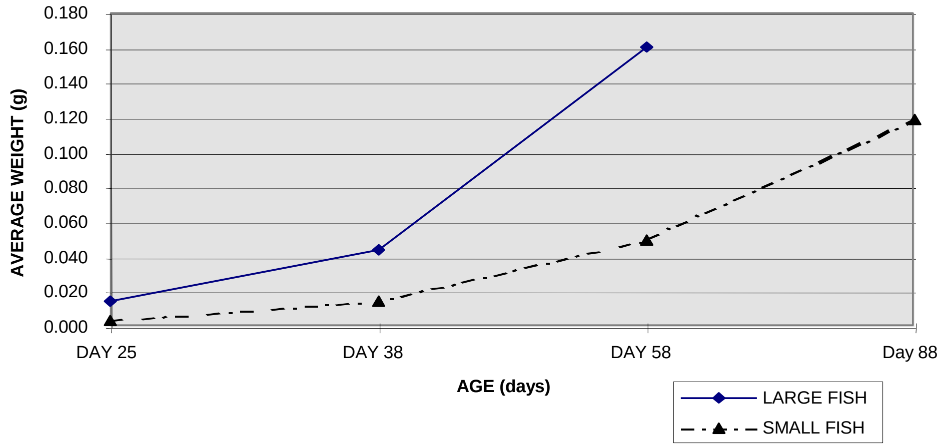

Figure 8. Growth of day old "Ningu" juveniles on dry diet (small and big fish)

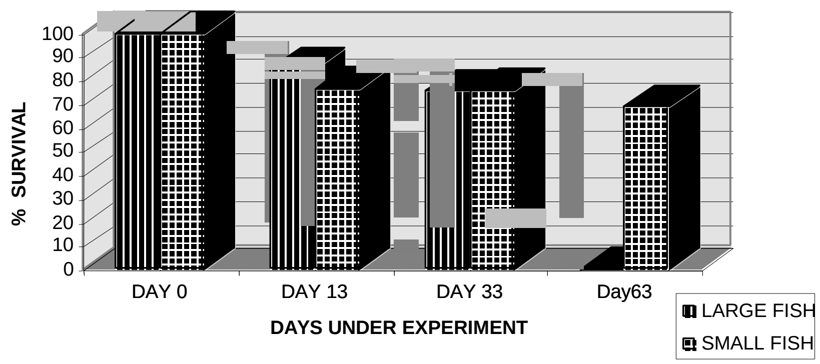

Figure 9. Survival of 25-day "Ningu" juvenile on dry diet. (Note: all the larger fish accidentally died during the sampling on Day 33 and therefore were not available for sampling on day 63

It was gratifying to learn that the local sunflower cake treatment gave good growth and survival of "Ningu" in ponds (Figures 10 and 11), which allowed continued observation of the feeding habits and development of the digestive system of the fish during growth.

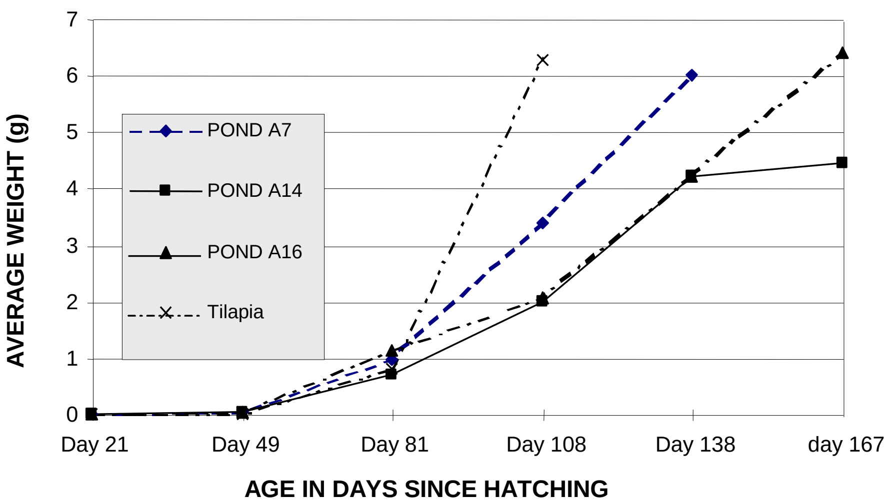

Figure 10. Growth of *Labeo victorianus* in ponds only fertilised with sunflower seed cake

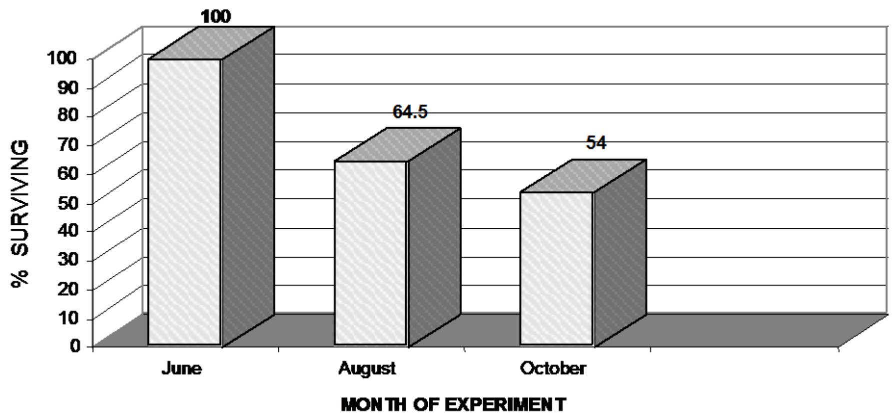

Figure 11. Survival of *Labeo victorianus* juveniles in ponds. The figures include the fish removed at each sampling for examination.

Discussion

The position and structures of the mouth of "Ningu" are adapted for bottom feeding and for scraping epilithic materials from surfaces of submerged objects and for filtering detritus. The relatively long gut of "Ningu" is typical of species feeding predominantly on plant diet. This further confirms the findings from analysis of the gut content of "Ningu".

The fact that the young juvenile "Ningu" has a relatively much smaller gut length - implying an animal diet - means that young "Ningu" starts on animal diet and then shifts towards more plant diet as it grows. Results of starter diet using zooplankton resulted in the best growth and survival of "Ningu".

The peaks in the relative gut fullness and relative quantity of mesenteric fat during the rainy seasons and the minima after the rainy seasons, coinciding with the spawning and recovering periods, respectively, suggests that *Labeo victorianus* feeds intensively just before, and in preparation for, spawning. Further, the fact that the peaks for mesenteric fat content are a little later on after the peaks in gut content suggests that as the spawning season approaches the food in the gut is converted into mesenteric fat as an energy store for the spawning process (Hunter and Leong, 1981; Dawson, 1986; Alheit, 1988; Kjesbu, 1989).

It is now clear that by the fifth day, when the yolk food reserve is almost exhausted, there must be adequate amount of zooplankton diet of the right size ready for the fry otherwise it starves to death. It took at least two weeks to culture reasonable quantity of rotifers. Therefore, the zooplankton culture needs to be set up at least three weeks prior to spawning of "Ningu".

The yolk sac food reserve is not quite completely exhausted by the time the "Ningu" larvae starts feeding on external diet. This period of overlap helps the young fish to perfect its hunting skills and for the digestive system to become sufficiently efficient before the food reserve is completely exhausted (Pitcher and Hart, 1982).

Results of the dry feed experiments showed that "Ningu" larvae are ready to take and utilize dry diet at 7.2 mm total length, i.e. at three weeks after hatching. This is good because the larvae of "Ningu" can be weaned to formulated diet quite early in life and may reduce on the cost of prolonged feeding on live food.

Both growth and survival of "Ningu" in ponds only fertilized with sunflower cake was impressive. The high survival rate (over 54%) of *Labeo victorianus* in ponds suggests that the fish will be easy to grow in ponds. The pond grown fish attained twice the average weight of "Ningu" of the same age group in the wild (Figure 10) with just pond fertilization, despite the fact that these fish had initially been kept in glass aquaria for over two months observing development of the digestive system prior to transferring into ponds. It is possible that un-delayed transfers into ponds and supplementing fertilization with quality diet will enhance the growth rate of "Ningu" several times over and above its growth rate in nature.

Conclusion

The fry of "Ningu" depends on the yolk food reserve for only five days and good quality food must be supplied to the fry starting by the fifth day of age otherwise the fry starves to death. Zooplankton, especially rotifers, are the best starter food for "Ningu" fry. After three weeks "Ningu" fry can be fed on plant and dry formulated diet. There is now sufficient knowledge about the feeding biology of the various growth stages of "Ningu" to allow formulation of the diets for the different stages.

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A study of impacts of fishing pressure on Nile perch fishery on Lake Victoria (Uganda) using fisher folk community collected data

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Abstract

Fishery management on Lake Victoria in Uganda is constrained by lack of an effective fishery monitoring and regulatory mechanism, coupled with inadequate budgetary allocations to the fisheries sub-sector. This has led to high fishing pressure and a decline in the fishery. This paper presents a preliminary analysis of fisher-folk data collected over a period of one year at four landing sites in four districts along Lake Victoria in Uganda under a co-management pilot project aimed at addressing some of the problems in the fishing industry. Gear type and size and catch size of Nile perch in the different gear types/sizes was examined. Results indicated a declining fishery. Around 62.7% of the fishing canoes that target Nile perch on the lake were using fishing gears and methods that catch high proportions of immature Nile perch. Around 7.1% of the canoes caught Nile perch that was predominantly immature and illegal. Some 43.4% of the Nile perch in the overall sample was smaller than the size at first maturity for males and around 99.7% was below the size at first maturity for females. Expansion of the project in space and time, together with a revision of the current fishery regulatory law is recommended to improve the fishery management on Lake Victoria.

Key words: Fishing pressure, Nile perch fishery, Lake Victoria-Uganda, co-management

Introduction

The fishing industry makes significant contribution to the welfare of Ugandans in terms of employment, food security, government revenue and foreign exchange earnings. Overall contribution to the gross domestic product (GDP) during the 1990's has been between 2-3% (State of the Environment Report - Uganda 1998). This contribution comes from an estimated annual production of some 200,000 to 250,000 metric tonnes of capture fisheries from a resource base of mainly lakes Victoria, Kyoga, Albert, Edward and George and River Nile and a few of the 165 minor lakes of western Uganda, rivers, dams, ponds and wetlands. Since the late 1980's Lake Victoria has been making the highest contribution (48%) to the country's annual production. However, the sustainability of the fisheries of this lake is uncertain due to unregulated increase in fishing effort leading to high fishing pressure. The fisheries of the lake are declining and fish stocks are being threatened with depletion. Ineffective monitoring, irregular assessment of the state of the fishery and lack of enforcement of fishery regulations abet high fishing pressures.

Commercial fishermen using prohibited fishing gears and methods are landing immature fish. Use of large mesh sized gillnets has been declining while that of small sized gillnets is on the increase. There is a marked presence of destructive fishing gears and methods. Number of gillnets of 203 mm have reduced from 45% in 1989 to only 2.7% in 2000. Around 23.2% of the fishing gears and methods on the lake are gillnets below 127 mm stretched mesh size, beach seines, cast nets and basket traps (Frame Survey 2000 Report; Kamanyi and Okaranoni, 1989).

These gears collectively catch relatively high proportions of immature fish and are indicative of a declining fishery (Ogutu-Ohwayo, 1994; Ogutu-Ohwayo *et al.*, 1997). Fishing effort has been rising, while catches are showing a decline. This suggests that maximum sustainable yield could have been exceeded and the fishery is moving to a state of stock depletion. Figure 1 summarizes the trends in fishing effort and total annual catches from Lake Victoria since 1970. There was an explosive increase in fishing effort in the late 1980's following the apparent explosive increase in stocks after establishment of the Nile Perch. Nile perch, together with Nile tilapia were introduced in Lake Victoria in the late 1950's and early 1960's. They gradually established themselves, with Nile perch becoming the most important in commercial catches by the late 1980's, followed by Nile tilapia (Ogutu-Ohwayo, 1994). Effort rose from less than 4000 fishing canoes in 1988 to over 8000 in 1990 and over 15000 in 2000 (UFD- Frame Survey 2000). Annual total catches also increased explosively. Catches rose from about 55,000MT in 1985 to about 132,000MT (an increase of 140%) in 1989 representing around 32% and 62% respectively of the national production. However, the catches declined after 1989, from 132,000 to 103,000MT in 1994 and have stabilized around that figure despite the increasing effort.

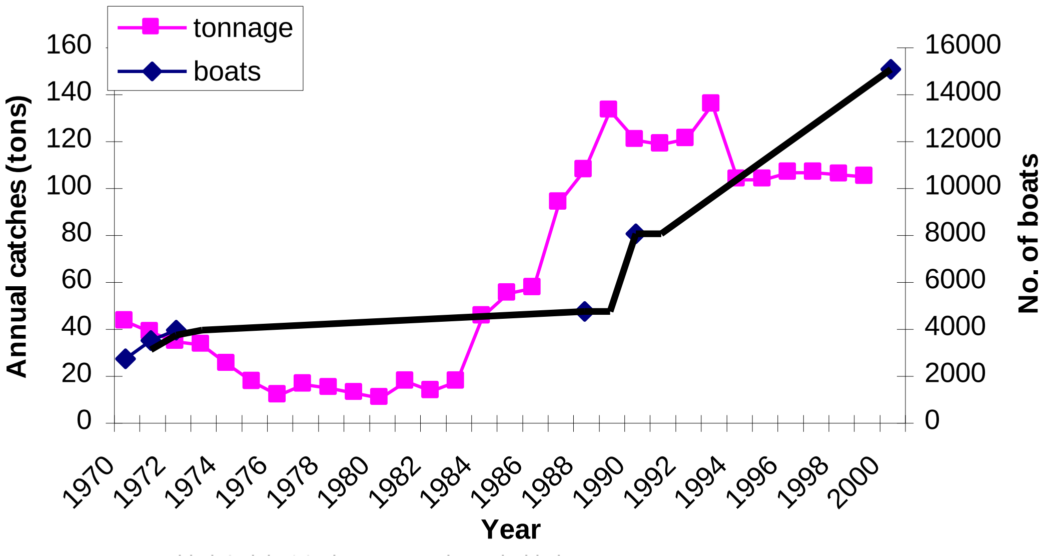

Figure 1. Trends in fish catches and fishing effort

The observed trends in effort and catches pertain to the hypothetical situation described in Sparre and Venema (1992). In a hypothetical situation, increase in effort leads to an increase in catch yields until up to a level of maximum sustainable yield (MSY). Once this level is reached any increase in effort will not result in increase in yields, but may instead result in a decline in yields and catch per unit of effort (CPUE). This indicates that the rate of renewal (individual body growth and recruitment) of the resources cannot keep up with the rate of removal by fishing. Decline in yields and in catch per unit of effort (CPUE) usually leads to fishermen deploying more canoes and a shift to use destructive fishing gears and methods (Ogutu-Ohwayo *et al.*, 1997). The overall result is a condition of high fishing pressure leading to over-fishing and depletion of stocks. There is enough evidence from observations on gear usage and catch/effort trends to suggest that the current commercial fishery is declining and the stocks are heading towards depletion.

High fishing pressure on Lake Victoria is a result of high demand for employment due to rapid population increase in the area (Ogutu-Ohwayo *et al*., 1997). It could also have been a result of high demand for the lake's resources due to improved marketing opportunities on one hand, and a decline in the capture fisheries in Lake Kyoga (Twongo, 1994). However, the main cause of high fishing pressure is lack of an effective mechanism for enforcement and monitoring of fishery regulations, coupled with poor budgetary allocations to the fisheries sub-sector.

The regulatory law (Fish and Crocodile Act of 1951) and the subsequent amendments were enacted without serious consideration to the biological and ecological dynamics of the fisheries resources of Lake Victoria. There are no restrictions on the level of effort. The law is silent on most fishing gears and methods that are destructive to the fishery.

The only prohibition is landing of Nile perch and Nile tilapia of less than 46cm and 28cm total length respectively (Fish and Crocodile Act 1964; Instrument No. 15 of 1981) and use of beach seines. The legally set minimum size of 46 cm for commercial Nile perch landings is less than the size at first maturity.

The fisheries monitoring system leaves a lot to be desired. There is no direct linkage between the collection and management of data on catch and effort and data on observations on the fish in the catches. Lack of integrated data collection and management is a hindrance to assessment of the state of the fishery. Fishery data on catches and effort are deficient in both coverage and reliability. Only estimates of annual yields have been recorded regularly. Other observable aspects like length and weight have not been regularly recorded (Okemwa, 1994). Without such data making sound management decisions is difficult. Observations on catch, effort and the fishery, together with observations on the fish (ecology and biology) in commercial catches can tell the state of the fishery and the effectiveness of the fishery regulations (Witte and Densen, 1995). A reduction in average size of fish in commercial catches would mean over-exploitation (Okemwa, 1994). Appropriate management decisions such as introduction of catch quotas; minimum mesh size, closed areas and socio-economic controls can only be taken based on such observations.

The Fisheries Resources Department (FRD), which is mandated with sustainable management of the fisheries resources, lacks adequate resources (personnel, financial and technical resources) to efficiently carry out its obligations. The department is quite often under-funded, and as a result operates below par. Functions such as catch data statistics are at times neglected (Fisheries Departmental Summary for the Minister in Charge of Fisheries, 1993). Lack of awareness and participation of the fisher-folk in the fisheries management processes makes the situation worse.

In an attempt to find a way to overcome the constraints, the Uganda Fisheries Resources Department - UFRD in 1999, under the Fisheries Management Component of LVEMP decided to undertake a pilot project in which the local fisher-folk were empowered to collect data on the Nile perch, under a co-management arrangement. This was after a recommendation by the 1999 World Bank supervisory team. The project was intended to provide adequate data for assessment of the state of the fishery at reduced costs and also promote fisher-folk participation in management processes of the fishery.

This report presents a preliminary analysis of the impacts of fishing pressure on Nile perch fishery on Lake Victoria in Uganda using data obtained from sampling commercial Nile perch landings by community beach collectors. The study specifically examines the distribution of canoes using different gear types/sizes and the size distribution of Nile perch catches caught by the different gear types/sizes. The report also makes suggestions and recommendations on areas that need improvement in order to achieve the project objective of providing reliable lake wide data for continuous assessment of the state of the fisheries.

Materials and methods

Data collection was done by trained community fisher-folk data collectors during the year 2000 at each of the four landing sites of Misonzi, Namirembe, Kiyindi and Lwanika in Kalangala, Masaka, Mukono and Mayuge (formerly Iganga) districts respectively. The landing sites were selected on the basis of predominance of Nile Perch fisheries and the accessibility of roads by vehicles. Districts were selected in such a way as to give a broad representation of the Ugandan portion of the lake. Two collectors selected directly from each landing site by the landing communities themselves were trained in the basic concepts of fish measurements, sampling, data recording and equipment handling and were left to continue with biometric and fishery data collection. Fisheries staff at the districts supervised the collectors. Fisheries headquarter staff made monthly checks whenever resources could permit to check on progress. Non–qualitative supplementary field data was obtained by direct observations and discussions with various fisher-folk during the headquarter staff monthly supervisory visits. Specially designed data forms were used for this purpose.

The completed data forms were collected monthly and information entered into EXCEL computer program for subsequent analysis using both EXCEL and SPSS computer programs at Makerere University Institute of Statistics and Applied Economics. Gear distribution was determined as percentage numbers of fishing canoes using a particular gear type/gillnet size. Data on total length of fish caught in each gear type/gillnet size were sorted into 3 cm class interval length-frequency distributions.

Results

A total of 5451 fish specimens were sampled from 464 fishing canoes. Gear encountered in the sample included gillnets, hooks and “other gears”. “Other gears”, wherever mentioned refers to basket traps, beach seines and cast nets. Gillnets are the most common gear in the current fishery, with gillnets of 127 mm as the most abundant. Gillnets account for 93.4% of all the canoes that were sampled; and of the 93.4%, 54.7% are gillnets of 127 mm. The rest of the gear accounted for only 6.6%; i.e. hooks, 4.7% and “other gears”, 1.9%.

The distribution of canoes using different gear types/sizes may slightly be different. Some fishermen who land fish using gillnets of less than 127 mm mesh size and “other gears” tended to hide, falsely declare, disguise them with other gear and/or at times land away from authorized landing sites for fear of their gear being confiscated by policing authorities. There was also a tendency for locally woven gear to have varying size of meshes within the same net. A number of fishermen used gillnets of different mesh sizes in a single round of fishing.

Fish specimens ranged from an average size of 21 cm TL to over 100 cm TL; the most common size of fish, i.e. the modal size fell between 48 and 51 cm TL; and the average total length was 46.9 cm. All the length frequency distributions of catches from each gear type/ size and for the whole sample tended to have normal distribution and each has its own specific distribution characteristics. The numerical values of the distribution characteristics of Nile perch from the different gear types/sizes generally became smaller and smaller when moving from hooks and large mesh sized gillnets towards small mesh sized gillnets and "other gears" and vice-versa. The upper and lower values of the size range of Nile perch catches dropped from 30 - 100 cm for hooks to 21 – 48 cm for "other gears". The size of Nile perch at the modal class dropped from 84 – 87 cm for hooks to 30 – 33 cm for "other gears". The average size of the catches dropped from 87.2 cm TL for hooks to 32. 2 cm TL for "other gears."

Analysis of catch size distribution showed that there was a relationship between the size of Nile perch caught and the distribution of the gear types/sizes being used in the current Nile perch fishery. A plot of average size of fish in centimetres against the mesh size of gillnet in inches tended to a linear relationship (Figure 2), with a linear-regression curve equation: y = 8.571+ 6.756x, S.E.= 1.06 and r = 0.954.

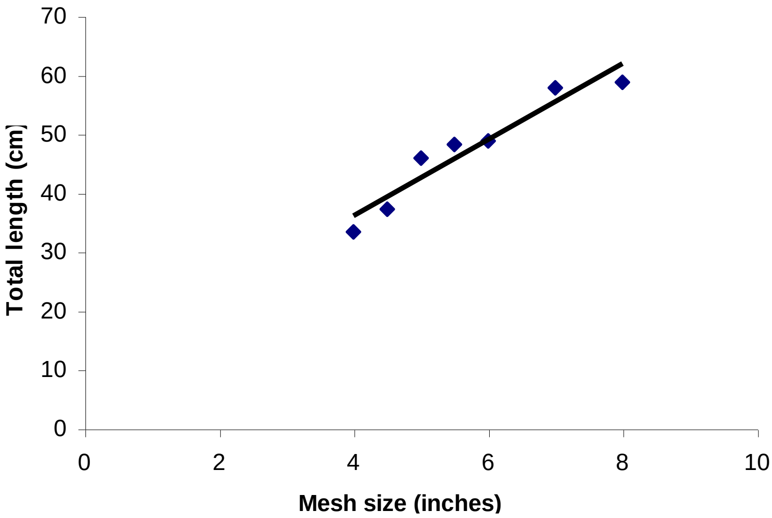

Figure 2: Gillnet mesh size/ total length relationship

The distribution of fish of small size groups could be different from what has been recorded. Most fishermen would come with fish already separated from the nets. The small fish of non-commercial value was usually thrown back into the lake as by-catch. The target market tended to dictate the minimum size declared by the fishermen.

Discussion

In fisheries management, the size limit of fish that should be cropped is normally set at size at first maturity, that is, the size at which 50% of the members of that species are mature (Beverton and Holt, 1957). This allows 50% of the fish to breed before they are harvested. The size at first maturity for Nile perch is 50 cm total length for males and 95-110 cm for females (Ogutu-Ohwayo, 1988). The regulatory law in Uganda, the Fish and crocodile Act CAP 254, 1951 and subsequent amendments, puts the size limit of fish to be landed by commercial fishermen at 46 cm TL. The fishery law also prohibits use of beach seines and trawl fishing on Lake Victoria waters. Therefore, landing of Nile perch below 46 cm TL and use of beach seines in commercial fisheries is both destructive and illegal. Also, many research scientists (e.g. Ogutu-Ohwayo, 1988; Ogutu-Ohwayo, 1994;) strongly discourage use of basket traps, cast nets and gillnets of less than 5 inches stretched mesh size. These fishing gears and methods are also destructive to the fishery.

Despite the existing law and the scientific research recommendations immature and illegal sized Nile perch are being landed by commercial fishermen in canoes using prohibited and discouraged fishing gears and methods, in large quantities.

This study shows that a fairly high proportion (43.4%) and almost 100% (99.7%) of the Nile perch are caught below size at first maturity for Nile perch males and females respectively; and around 31.2% are caught below the minimum legally permitted size. The proportions of immature and illegal sized fish varied from one gear type/gillnet size to another.

Gillnets of less than 127 mm mesh size and “other gears” caught very high proportions of immature and illegal sized Nile perch, with an average of 90.5% and 84.2% of the catches smaller than 50 cm TL and 46 cm TL respectively; and all the catches were below 95 cm TL. These gears constituted 7.1% of the fishing canoes in the sample. Gillnets of 127 mm, 139.7 mm and 152 mm caught fair proportions of immature and illegal sized Nile perch, with an average of 30.6% and 27.3% of the catches smaller than 50 cm TL and 46 cm TL respectively; and all the catches were below 95 cm TL. These gears constituted 76.9% of the fishing canoes in the sample. Gillnets of 177.8 mm and 203.2 mm and hooks caught quite low proportions of immature and illegal sized Nile perch, with an average of only 8.1% and 6.8% of the catches smaller than 50 cm TL and 46 cm TL respectively; and at least 7.4 % the catches were above 95 cm TL. These gears constituted 15.9 % of the fishing canoes in the sample.

The use of gillnets of less than 127 mm-mesh size and “other gears” should be prohibited. Apart from catching high proportions of immature and illegal sized Nile perch, some of them (“other gears”) also disrupt the biological and ecological processes of the fishery during their operation (Ogutu-Ohwayo, *et al.,* 1997). Although Gillnets of 127 mm, 139.7 mm and 152 mm showed fair proportions of immature and illegal sized Nile perch, there is need to find out their impacts on the recruitment potential of the Nile perch.

They are the most popular with the highest distribution among the sampled canoes. Exploitation without research could be dangerous and can lead to gross over fishing. This is more so among the females, which mature at 95- 110cm total length. Gillnets of more than 152 mm and hooks have been shown to catch quite good Nile perch their use should be encouraged, if possible the users could be given economic incentives.

Excessive use of gears that catch large numbers of small sized fish is not only destructive to the fishery but also leads to reduced overall catch yields. The results have shown that the average size of individual Nile perch generally became smaller and smaller when moving from hooks and large mesh sized gillnets towards small mesh sized gillnets and “other gears” and vice-versa (Table 1). Regression analysis on gillnet mesh size and size of fish showed that average total length TL in centimeters increases with increase in mesh size of gillnet M in inches by 8.571 + 6.756M, S.E.= 1.06 and r = 0.954. This implies that the higher the proportion of canoes using small mesh sized gears the higher the number of small sized Nile perch and the poorer the total catch yields. This could perhaps explain the declining levels of annual fish catches despite the increasing effort on the lake.

Table 1: Summary of impacts of different gear types/sizes on size of Nile Perch catches

(key to the table 1 a =gear type/ size; b =average tl; c = % of fish below 46 cm tl; d = % of fish below 50 cm TL; e = % of fish above 95 cm TL

A	B	C	D	E
“OTHER GEARS”	32.2	90	90	0
GN4	33.4	93.2	95.5	0
GN4.5	37.2	69.4	86.1	0
GN5	45.9	32.2	45.5	0
GN5.5	48.2	26.6	48.2	0
GN6	48.8	23.5	35	0
GN7	57.8	4.7	8.5	4.7
GN8	58.8	10	10	0
HOOKS	87.2	5.8	5.8	17.4
WHOLE SAMPLE	46.9	31.2	43.4	0.3

Most management techniques applied in regulation of the fishery are meant to protect the fishery from over-fishing and disruption of biological and ecological processes. The techniques include restrictions on gears and size of catches, closed seasons and areas and restrictions on fishing effort. Very few of these options have been applied on the fisheries of Lake Victoria in Uganda. The lake is more like an open fishery. This relaxed regulatory practice coupled with poor monitoring practices, has resulted in the declining trends in the Nile perch fishery.

The falling trends in annual catch yield despite the rising effort and use of destructive gears and methods and the big proportion of immature and illegal sized Nile perch in the sample is a clear manifestation that the stocks have considerably declined.

The situation is likely to continue unless the constraints that are causing high fishing pressure are checked. This pilot project presents an opportunity for addressing some of the constraints such as lack of fisher-folk participation in the management processes. Most important, it provides a data collection and management system that integrates data on catches and catch per unit effort, and observations on the fish in the catches. There is also urgent need to review the current fishery regulations to include clauses that will protect the Nile perch from the destructive fishing practices.

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Fish introductions and their impact on the biodiversity and the fisheries of Lake Victoria.

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Abstract

Recent fish introductions in Lake Victoria have had both positive and adverse implications on its biodiversity and fisheries. This paper reviews the impact of six introductions in Lake Victoria basin with emphasis on areas where the introduced species have put more risks or benefits to the host environments. There have been six introductions of fish species (*Lates niloticus, Oreochromis niloticus, Cyprinus carpio, O. melanopleura, O. leucostictus* and *Tilapia zillii*) in Lake Victoria in a span of 20years. A significant ecological imbalance has been created through the depression of haplochromiine cichlids, changes in food webs and food chains, and alterations of water quality. There is evidence for example, that the introduced *O. melanopleura* has crossbred with *T. zillii* while *O. niloticus* has crossbred with *O. variabilis* with apparent dominance of the introduced species in these hybrids. The native species *(Labeo victorianus, Barbus spp, Haplochromis spp., Protopterus aethiopicus, Bagrus docmac, Clarias spp, Alestes spp, Synodontis spp* and the native tilapia species) have declined considerably in the commercial catches in the last few decades. On the other hand, it has been a great boost to the riparian communities, and Kenya as a whole from the increased commercial fish landings from less than 20,000 m.tons in the 1970's to over 193,000 m. tons in the 1990's. Presently, the introduced *L. niloticus* and *O. niloticus* compose over 70% of the total landings by weight. Fish protein food supply has increased significantly; number of fishermen now is over 36,000 (up from 11,000 in the 1971) with the export sector directly employing over 500,000. Given the dependants as well as those engaged in the auxiliary activities in this sector, the fishing industry currently supports over 1 million people. On the other hand, a significant nutritional loss has also been noted as a result in the decline in the local's favourite fish species (endemic species) in the catch. With the market expansion, the local community have been reduced to low-grade fish, which do not meet the export requirement and fish skeletons. The only native species landed in large quantity is the *Rastrineobola argentea*, which has gained popularity for its use as animal feed. There is urgent need to document all fish introductions in this country with appropriate evaluation of each case from time to time. This evaluation report will contribute to the development of guidelines to introduction programs in future. The need for research in order to better anticipate with confidence the cost of any introductions before such programs are implemented cannot be overemphasised.

Key words: Introductions, Alien species, Endemic species

Introduction

Fisheries' managers all over the world often use stocking, transfer and introduction of fish as management techniques. Types of fish introduction range from stocking with resident species through to release of exotic species. The term "introduced species refer to any species intentionally or accidentally transported and released into an environment outside its present range. In this paper however, one reservation is made with respect to this definition in that a species is considered to have been introduced to a country once it has crossed national boundaries as adopted by Welcomme (1988). It however excludes the many more introductions made between river basins within national territories.

A total of 1354 introductions of 237 species into 140 countries have been documented world-wide (Hickley, 1994; Pitcher, 1995). Africa has experienced 147 introductions of 50 fish species, 23 of these from outside Africa. In Kenya's freshwater lakes about 14 introductions have received due documentation with 6 introduced species in Lake Victoria, 7 in Lake Naivasha and 1 in Lake Baringo. It is worth noting at this point that this list is far in-exhaustive. The major reasons for the introductions in Kenya's freshwater lakes are:
(i) Enhancement and /or supplement stocks in order to improve the fisheries.
(ii) Recreation (aquarium /ornamental fisheries)
(iii) To provide sport fish to attract tourism
(iv) To fill an apparently vacant niche
(v) Control weeds and disease vectors; mosquitoes and snails.
(vi) Accidental together with other fish or as escapees from fishponds.
(vii) Create a commercial fishery

Introduction of fish species in Lake Victoria basin, like elsewhere in the world, has had both positive and negative implications. On the adverse side they have been accused of eliminating the native species through competition and /or hybridisation as well as altering their gene pools. Farther, they have been reported to cause or initiate ecological imbalance (LVEMP, 1999; Ochumba *et al*., 1994). Without denying the importance of the concern about the adverse effects, a great deal of benefits has been realised due to the introductions and associated developments. It has seen a big boost to the total quantity of fish landed from these lakes and other benefits associated with this have been evident. However, it has been observed that the significance of, and risk associated with, fish introductions depend very much upon the relationship of the candidate species, the type of fishery and fish community into which it is being placed.

Objective: This paper was aimed at reviewing the status of knowledge regarding introductions of fish species in Lake Victoria basin.
Method: Method used in collection of this information include reviews of existing publications, field reports and Frame Survey 2000 report in the department of Fisheries, Ministry of Agriculture and Rural Development.

Fish introductions in Lake Victoria basin

Six exotic species have so far been introduced into the Lake Victoria basin. These are *Lates niloticus, Cyprinus carpio, Tilapia zillii, Oreochromis niloticus, O. leucostictus* and *O. melanopleura* (Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991; Welcomme, 1988). According to Reynolds *et al*. (1995), *L. niloticus* (Nile perch) was introduced in Lake Victoria by officials of the Uganda Game and Fisheries department between 1954 and 1957. This first placement seemed to have been carried out surreptitiously and other two official introductions were made in 1962 and 1963. The Nile perch later found its way through the Nyanza Gulf and by 1982 had colonised the whole lake (Witte &

Dansen, 1995). Okemwa and Ogari (1994), Ochumba *et al*. (1994) and Ogutu-Ohwayo & Hecky (1991) gave an account for the introduction of the tilapiine species as follows. *T. zillii* was introduced to fill an apparently vacant niche of a macrophytophage, whereas *O. niloticus* and *O. leucostictus* were introduced to supplement stocks of the native tilapiines, which had declined due to overfishing. *O. melanopleura* was introduced accidentally from fishponds.

A number of writers, e.g., Okeyo-Owuor, 1999; Abila, 1998; Pitcher & Bundy, 1995; Reynolds *et al*., 1995; Ochumba *et al*., 1994; Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991) have given an account of the introduction of the *L. niloticus* into the waters of Lake Victoria. The main reasons noted are to provide sport fish to attract tourism and improve the fisheries. The perch was introduced supposedly, to feed on the smaller sized haplochromiine cichlids that were at that time abundant but of lesser economic value, so as to convert their biomass into larger table sized fish. Where-as *L. niloticus* and *O. niloticus* have overly established in the lake, *C. carpio* and *O. melanopleura* have not appeared in the catch.

Biological implications of fish introductions

The impact of introduction in Africa has perhaps received a high public profile on account of the concern about the effects of Nile perch on endemic fishes in Lake Victoria. According to Manyala (1999), the early fishery of Lake Victoria (in the 1920s) was dominated by haplochromine cichlids and the endemic tilapiines, the lungfish, catfishes and several cyprinids. Upto the early 1970's, these endemic species constituted over 83% (about 564,000 metric tons) of the total demersal ichthyomass in the lake, with an estimated annual potential yield of 200,000 metric tons. Okemwa and Ogari (1994) noted that as the catch rates for the indigenous tilapia i.e., *O. esculentus* and *O. variabilis*, declined in the 1970's due to overfishing, attention was directed to the large quantities of the relatively un-exploited haplochromines. Although never adequately exploited as a fishery, the flock of haplochromine species in L. Victoria was one of the world richest comprising more than 300 endemic species. Ogutu-Ohwayo and Hecky (1991) reported that this diverse group of fishes had undergone adaptive radiation and occupied many trophic levels. It contributed to the understanding of the process of evolution by adaptive radiation and its decimation is a great loss to evolutionary science.

The most prominent biological effects of fishes introduced can be divided in three categories. The first include species that have directly through predation and indirectly through competition depleted or even eliminated resident species. The second include genetically and ecologically related species, which have eliminated others through competition and /or hybridisation. The third includes species that have caused or initiated environmental degradation.

Predation and competition or competitive interactions

Introduced piscivorous fish almost always decimate or even eliminate many of the resident species in their new habitats (Kodhongania & Chitamwebwa, 1995; Ochumba *et al*., 1994; Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991). Nile perch introduction in Lake Victoria provides a spectacular example of the effects of introducing a large predator into a lake. As the population of Nile perch increased, many native species declined and some completely disappeared. Although the decline may have been initiated by human exploitation, Ogutu-Ohwayo and Hecky (1991) noted that predation by Nile perch certainly contributed to the final elimination of many of the native species**.** Soon after its introduction into Lake Victoria, it was observed that most sizes fed almost exclusively on haplochromine cichlids and a rapid decline of the latter was reported. It was further noted that the landings of other native inshore genera such as *Tilapia*, *Protopterus*, and *Clarias* also declined. By 1980's, the endemic fishes, espcecially the anadromous cyprinids and mormyrids were too scarce to support a significant fishery (Ochumba *et al*., 1994). Manyala (1999) indicated that out of the 300 haplochromine cichlid species which existed in Lake Victoria before the introduction of Nile perch, 200 are thought to be extinct. Arthington (1991) and Fausch (1988) however observed that resource competition for food, and space perhaps mediated by interference and aggression, seems to be one of the most probable mechanisms of the impact of introduced species other than just predation. Currently, the lake has been reduced to a three species fishery of *L. niloticus, O. niloticus* and *R. argentea* the with the two species forming over 70% of the total fish landings by weight.

Hybridisation and competition

It has been noted that the tilapiine species form hybrids, and upon introduction, introgressive hybridisation may lead to genetic changes in the surviving species. Such has been reported as a consequence of some introductions followed by other forms of reproductive isolation such as infertility (Krueger & May, 1991). Kudhongania & Chitamwebwa (1995) reported that the establishments of the four exotic tilapiines in Lake Victoria introduced intra-specific competition with the indigenous species and enhanced the likelihood of genetic dilution through hybridisation. Studies on the life history of the indigenous tilapiines in Lake Victoria indicated that availability of suitable spawning sites was the most important factor limiting populations. The native tilapiines were spatially segregated, with the smaller *O. variabilis* being more inshore than *O. esculetus*. When *T. zillii* and *O. leucostictus* became established, they occupied the same habitat as *O. variabilis*. Such competition was also observed for nursery grounds (Ogutu-Ohwayo & Hecky, 1991). Although competition for food among indigenous tilapiines was thought to be insignificant, *O. esculentus* feeding only on planktonic diatoms was at a competitive disadvantage *to O. niloticus*.

Kudhongania and Chitamwebwa (1995) and Ogutu-Ohwayo and Hecky (1991) noted that hybridisation must have led to the restructuring of the tilapiine communities in Lake Victoria. Hybrids between *O. niloticus* and *O. variabilis,* and between *T. zillii* and *O. melanopleura* were identified in Lake Victoria with apparent dominance of *O. niloticus* in the crosses. Similar scenario was observed in Lake Naivasha where mixing of tilapiine *spp*. as a result of introductions appear to have resulted in elimination of some species through hybridisation and /or competition. Hybridisation between *O. leucostictus* and *O. spirulus* was followed by the disappearance, first of *O. spirulus* then the hybrids from this lake. On these grounds it is also suspected that the disappearance of *O. esculentus* and *O.*

variabilis of Lake Victoria could be due to hybridisation and /or competition with the introduced tilapiines especially *O. niloticus* and *T. zillii*. *O. niloticus* was however reported as a superior competitor with its wide food spectrum, high fecundity, faster growth rate longer life span and growth to larger sizes than the endemic *Oreochromis spp*.

Allendorf (1991) observed that the genetic effects of introductions constitute a threat to the long-term existence of many wild populations and species but are often more difficult to detect and monitor than demographic or ecological effects. Separating contributions of hybridisation, competition, and predation and over-fishing to the demise of the endemic *Oreochromis spp*. in the case of Lake Victoria is difficult to ascertain. This is because these processes may happen concurrently.

Ecological alteration

Trophic cascade theory predicts that increased piscivory that may result from introductions, should lead to a reduced phytoplankton and water clarity through a cascade of interactions. A similar cascade effect could be initiated by increasing the abundance of zooplanktivores (Ogutu-Ohwayo & Hecky, 1991). The haplochromines are grazers and feed on the dominant and /or bloom forming blue-green algae and detritus. It has been observed that their absence could partly be responsible for the enhanced algal blooms and detritus accumulation in the deep waters (Manyala, 1999; Ochumba, 1995). Okemwa & Ogari, (1994) also noted this could be a cause of increased de-oxygenation observed in the deep layers. Fish introductions have modified the phytoplankton, zooplankton and fish assemblages in the lake with resultant impact on the water quality. Owing to these, many writers (see LVEMP, 1999; Muli, 1996; Ochumba, 1995; Ochumba *et al.*, 1994) have reported that Lake Victoria fishes are under threat.

Socio-economic impacts of fish introductions

Despite the ecological and genetic outcomes of fish introductions, increases in production have been of much benefit to the people of various parts of Africa. Malnutrition is a concern in many countries. In the vicinity of lakes and rivers, people depend on fish as their cheapest source of animal protein. Nile perch and the Nile tilapia that were introduced into Lake Victoria have so far resulted in tremendous increases in the quantities of fish landed (Reynolds *et al*., 1995; Ogutu-Ohwayo & Hecky, 1991). Some decades have now passed since the original introductions of Nile perch into Lake Victoria waters, and the attendant controversy, far from diminishing, seems to have proliferated almost as rapidly as the fish itself. Sometimes assuming quite sensational, strident and bitter expression, spilling over from professional fisheries' circles into the popular literature and press (Reynolds *et al*., 1995).

Without denying the importance of the concern about ecological and other disruptions to the lacustrine system and dependent human populations, a great deal of development has been realised due to the introductions and associated changes, and that more may be forth coming. Ogutu-Ohwayo and Hecky (1991) reported that the total quantity of fish landed from Lake Victoria has increased between two and six folds following establishment of

Nile perch and the Nile tilapia. In the Kenyan part of the lake, the annual commercial catches increased from 20,000 metric tons in 1977 to 192,740 metric tons in 2000 hitting a peak of over 193,652 metric tons in 1994. The socio-economic benefits can be seen in three basic categories; nutritional benefits, employment benefits and, market expansion and export earnings.

Nutritional benefits

Special emphasis is given to the nutritional welfare benefits that have accrued under the new regime of introduced species of Lakes Victoria for riparian and regional populations. This lake has always served as an important source of fish for those living within the immediate area but its importance to markets across the wide East African region has until recently been relatively minor. With the introductions in Lake Victoria and the conditions developed under the post-Nile perch regime, this situation was transformed**.** This lake now serves as fish supplier not only to broad sections of East African region, but also to overseas markets (Fisheries Department, 1999; Jansen *et al*., 1999; Okeyo-Owuor, 1999; Pitcher & Bundy, 1995). Also to be taken into account is the considerable volume of sun-dried, smoked and salted fish products. These move to remote markets within the three riparian states and as exports to Sudan, Zaire, Rwanda and Burundi.

Pre-Nile perch regimes saw the Lake Victoria fishery shift towards *R. argentea* and the haplochromiines that could not withstand heavy commercial exploitation. With the enhancement of fish stock through introductions, there is no doubt that many new consumers gained tremendously from the changes having effected the rich Lake Victoria fisheries. During the 1980's, high amounts of fish were made available, from this Lake Victoria, at more affordable prices throughout the large portion of the three East African countries (Jansen *et al*., 1999). Abila (1998) observed that the major objectives of introducing the perch into Lake Victoria have been met and perhaps even beyond expectations.

Employment benefits

With the rich Nile perch fishery, opportunities were created for employment and thereby increased participation in the harvesting sector (Jansen *et al.*, 1999). At the production level, Frame Survey 2000 for Lake Victoria indicated that the fishery of Lake Victoria is supporting more operators. Records on the Kenya's part of Lake Victoria show an increment in the number of fishermen in the harvesting sector from 11,000 in 1971 to 36,159 in march 2000 (Fisheries Department, 2000). The number of canoes has increased to more than double (to 11,515 canoes) over the same period. The effect is multiplied when landing-site activities such as portage, net making and mending, canoe construction and repair, and fish processing and marketing are taken into account.

Market expansion and export earnings

Interests in possibilities for large-scale commercial processing and overseas export of Nile perch fillet first grew in Kenya from around 1985. This country still acts as a host to 12 industrial plant activities linked to the lake. In 1997, about 5.3 mil. tons of Nile perch products valued at over Kshs 863 mil. were exported by fish processing factories based in

Kisumu Municipality alone, with over 57% of the exports going to markets bound by the European Union (Fisheries Department, 1997).

Socio-economic displacement

Increased competition for fresh fish at major landing sites has frequently been noted. This has had the effect of driving up ex-vessel prices and these increases are eventually passed on to the consumer. This tendency is distressing for low-income people, as fish has been in the past been very attractive to buy in comparison with other forms of protein. One outcome of the situation is a move by consumers to seek a low-grade or cheaper fish. These come in the form of undersized or immature Nile perch /tilapia or by-products (skeleton and off-cuts) of the former from fish filleting factories. Competition for the fresh fish gives more fear for stock over-exploitation.

Other impacts

Other kinds of impacts (alleged, or real, likely or remote) have been associated with developments in the post Nile perch regime relates to culture, beliefs and superstitions. Some potential consumers developed real or imagined allergy to the fish flesh. For other different reasons; - medical, taboos, odour, taste, cultural factors and bad believes about Nile perch, some riparian folk resent it to date. In this point of view, they consider its introduction to Lake Victoria an overwhelming loss of the mouth-watering dishes (Osienala 1996).

Assessment of success/ failures of introductions

It is difficult to assess the success for a variety of reasons. The primary problem stated by Allendorf (1991) is that fish introductions are often made without appropriate mechanisms to evaluate if the desired objective(s) is achieved. The evaluations that have been done often ignore possible effects of the introductions on other taxa such as native fishes, amphibians and invertebrates. Exaggerated and undocumented claims of success often made by those responsible for the introductions have been observed to compound the problems.

Geographical and temporal scales of comparison have been used to evaluate successes, but have been observed to present several problems. For example, in many cases, introductions have increased the number of species existing within a particular geographical or political area. Viewed on this narrow scale, introductions may appear to increase biodiversity. However, such introductions also have caused extinction of many species. Thus on a global scale, such introductions reduce biodiversity. The temporal scale is also very important to consider Allendorf (1991). Any beneficial effects of introductions usually occur immediately while the harmful effects are often delayed. Thus, we are always faced with political and economic pressure to embrace short-term benefits at the cost of the long-term well being of an ecosystem.

Another difficulty of scale in evaluating introductions is the units with which we measure success or failure. The desire benefits of introductions are usually some short-term aspects of human well-being (for example food or recreation) or profit. The overall effect of such introductions often involves these two measures balanced against a loss in biodiversity. This is difficult balance to evaluate, for example how much money is a species of fish worth? How about an endemic invertebrate species? A review of the history of fish introductions all over the world indicates that most purposeful introductions have not achieved their objectives. Most important, any benefits of introductions have come at considerable costs.

General recommendations

From the foregoing, the need to fully understand and minimise threats of introductions before such programs are implemented cannot be overemphasised. The introductions should only be objective driven and appropriate mechanisms of evaluation and monitoring of the desired objectives should be an integral part of this effort. Allendorf (1991) recommended education, co-operation, regulation and research as the key issues when dealing with species introductions. Many passed and current arguments in favour of introductions have been based upon perceived societal demands. The society must realise that such introductions involve a *"cost*" and we do not understand natural systems sufficiently to know what the *cost* will be. There is a need to increase effort to educate the public and management agencies on the limitations and dangers of fish introductions.

Co-operation among management agencies is essential. Unfortunately, management objectives and responsibilities usually are defined upon political rather than the geographical or biological boundaries. Management agencies must consider the potential long-term effects of introductions inside and outside their areas of geographical and taxonomic responsibilities. Management decisions as regards to fish introductions should be done by umbrella management agencies rather than individual states being let to pursue their own agenda. Regulations and policies should be developed and enforced that recognise and encourage co-operation among responsible agencies to protect natural ecosystems. Researches being critical, there is need to be able to better anticipate the effects of proposed introductions. In this context, Waples' rule of introduction of " ***first, do no harm***" has become universally accepted (Allendorf, 1991).

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Overview of Lake Victoria frame survey 2000 - Uganda

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Abstract

This paper gives observations made on the frame survey that was carried out on the Uganda part of Lake Victoria in March 2000. The paper highlights the major changes affecting fishing, fishing gears and facilities in the industry on the Ugandan controlled waters of Lake Victoria. The method of using communities as a cost effective method of data collection was effective and allowed timeliness in collecting results. Data collection was supervised by technical staff and processed in a harmonized approach agreed on by the three East African frame survey scientists.

Mention has also been made of the survey costs in order to spell alertness to the survey activities planned for future. Strategies to overcome problems encountered in Frame Surveys 2000 have also been mentioned.

Keywords: Frame survey, fish landing, boats, fishermen, fishing gear

Introduction

Lake Victoria is the second largest lake in the world having a surface area of 68,000 km^2. It is shared by three riparian countries, namely: Tanzania, Kenya and Uganda. Uganda manages 30,720km^2 of the lake area. However, the exploited water in Uganda part of the lake constitutes only 18,000 km^2 (Walker, 1971).

The shoreline length on the Uganda part of the lake is at a magnitude of 2,400Km, and is mainly composed of sheltered bays, which are surrounded, by papyrus, swamps and gulfs at a number of places. The exploitable volume of water is 1,000 km^3.

A number of inventory surveys (Frame Survey) have been conducted on lake Victoria, Uganda, in recent years. Various methods have been used in these surveys but have mainly been aerial counts and in one instance supported by area transects to check the results (Graham, 1972a, 1972b). Water approach was used by Uganda Fisheries Department (UFD), 1990 and now FS2000 has combined a water and land approach using community participation strategy.

Objectives of Frame Survey 2000

1. Frame Surveys in the Fisheries sub-sector are carried out to determine, among others the structure of the fishery. Information is generally obtained on Landing sites, fishing vessels, fishing gears, fishermen and their socio economic status.

2. Pave way for designing catch and effort assessment surveys.

3. Provide benchmark data for further fishery management options.

4. Obtain a frame for designing socio economic surveys.

5. Study changes taking place in the structure of industry in time.

6. Evolve management action plans

Materials and methods

Coverage

The surveys covered shorelines of the ten Administrative Districts across Lake Victoria catchment including all-islands (Kalangala District) in the middle of the lake system. Data was collected on administrative units, fishing crafts details, facilities and utilities, staffing and usage of landing sites. Two hundred community based enumerators were recruited and assigned to fish landing sites at a ratio of 1:4.(based on 1990 estimates of 715 landing sites). The survey lasted for four days (22^{nd} – 25^{th} March 2000. Supervisors were the district and sub-county Fisheries Officers. Enumerators used either a bicycle or canoe to cover allocated areas.

Data collection

The questionnaire forms for the survey were developed by a co-operative effort of Research and Management Institutions of the three countries and harmonized at a series of regional meetings. These forms were delivered to district and sub-county officers during the supervisors training held at Colline Hotel, Mukono, on 16^{th} March 2000. Subsequently recruited enumerators assembled at sub-county's headquarters and got trained on the survey approach, data forms, and record entry by the supervisors. Upon completion of the training they were handed the fresh questionnaires to commence the exercise of landing sites enumeration.

Data processing

In preparation for processing of the survey data, a one-week course in computer data processing was organized for the three countries in Dar-es-Salaam, Tanzania, from 17^{th} –22^{nd} April 2000. Three officers from Uganda attended the training (1 Researcher, 2-Management). A data processing program was developed during the training. The data has since been successfully stored into a Microsoft Access database.

Data quality

Control of non-sampling errors was done through a number of steps, namely:

(a) Training of district and sub-county supervisors who in turn trained enumerators on the survey forms.
(b) Follow up ground supervision and later editing the returned questionnaires with the enumerator to verify or validate the entries for coverage, completeness and adequacy. (giving reduction of coverage and non response errors).

(c) Issuance of detailed guidelines and instructions to supervisors at district, sub-counties and headquarters geared toward quality control measures.
(d) Completed questionnaires were returned to the Headquarters two weeks from the end of the survey period. This gave the District Fisheries Officers ample time to go through all returned questionnaires at base to observe omissions or commissions.
(e) During the survey four teams from the headquarters and Research (FIRRI) traveled to different districts to note problems encountered and give remedy as appropriate.
(f) Recruited data entry personnel were of sound background in computing with hands-on experience in data entry activities.
(g) Interviewing knowledgeable people at beaches

Results

Frame survey overview

A lot of changes have occurred in the structure of the fishing industry over the past thirty years: namely, numbers of fishermen, Fish landing sites and fishing boats.(Table 1).

Table 1: overview of frame survey in Uganda

S/N	YEAR	No. Fish Landings	No. Fishing Boats	Authority	Method Used
1	1970	620	2,643	Wildlife Services Ltd	Aerial (10 days)
2	1971	197	3,264	EAFFRO/FAO	Aerial
3	1972	--	3,002	Fisheries Department	Aerial
4	1988	291	3,470	MAAIF, Planning Dept.	Land Based
5	1990	715	8,674	Fisheries Department	Water & Land
6	2000	597	15,544	Fisheries/LVEMP/ LVRFP Projects	Community, Water & Land

*1970 there were 10,572 fishermen
*2000 there were 34,889 fishermen

Fishing communities and their activities

The fishing community has steadily increased on Lake Victoria over the years. In 1970 there were 10, 572 fishers; In 2000, there were 34,889 fishers reflecting an increase of 69.7%.

Fish landings

In the same period the number of fish landings around the lake has ranged between 197 in 1971 to 715 in 1990 showing an increase of 72.03%. Figure 1. is a summary of the number of landing sites from FS2000. Highest numbers are in Mukono, Kalangala Bugiri, Mayuge, Mpigi, Masaka, Jinja, Rakai, Kampala and Busia districts in that order.

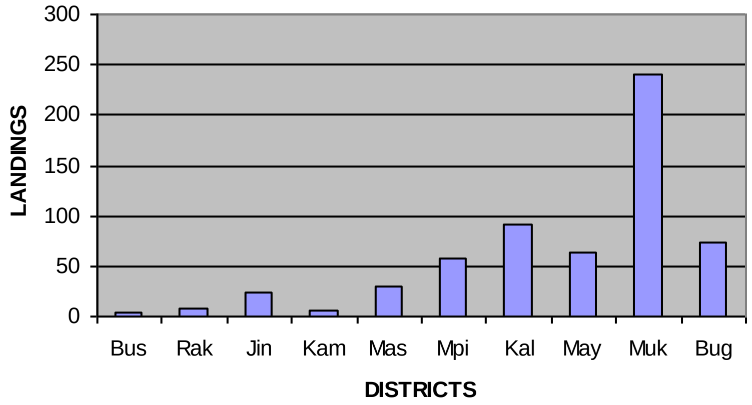

Figure 1 Number of fish landing sites by districts

Fishing boats

The number of fishing boats increased form 2,643 in 1970 to 15,544 in 2000. i.e. an showing 80.4% over the thirty years period. A total of 2,777 boats (14.35%) lay derelict on beaches. Mukono, Kalangala and Mayuge and Bugiri disytricts lead the rest in the high number of fishing boats (Fig.2).

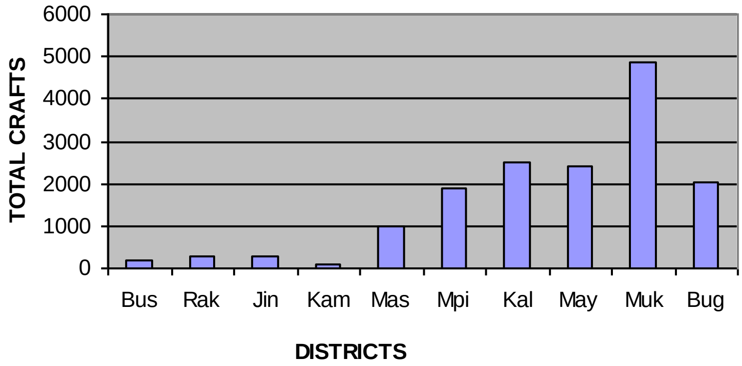

Figure 2 Number of crafts by district

Fishing crew

A total of 34,889 fishermen was recorded. Mukono, Kalangala and Mayuge districts had the highest number of fishers in the lake region (Figure2b)

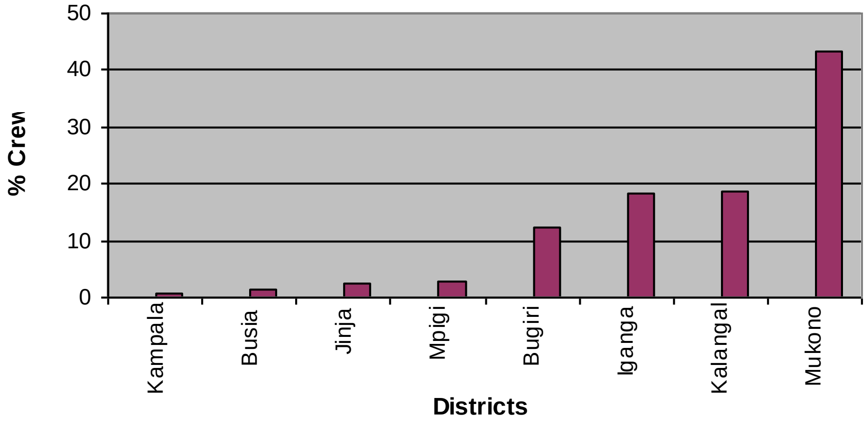

Figure 2b. Total crew by district

Boat propulsion

A total of 2031 boats used outboard engines (13.1%) while 12,848 boats were paddled (82.6%). Boats with sails were 665 and made up only 4.3% of total fishing boats.(Figures 3, 4 and 5).

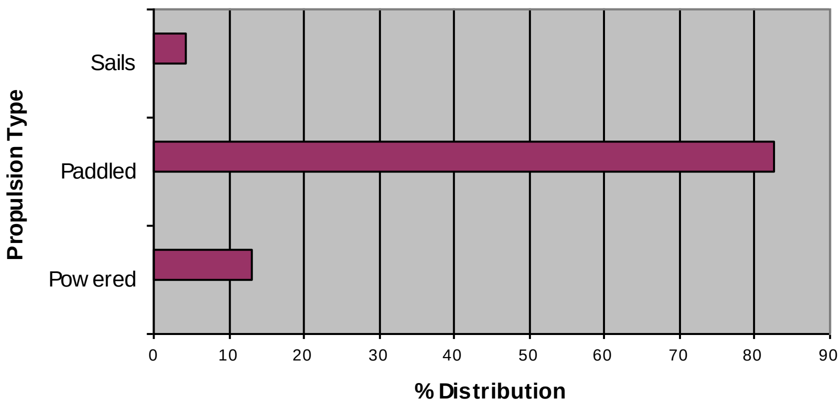

Figure 3: National status of boat propulsion

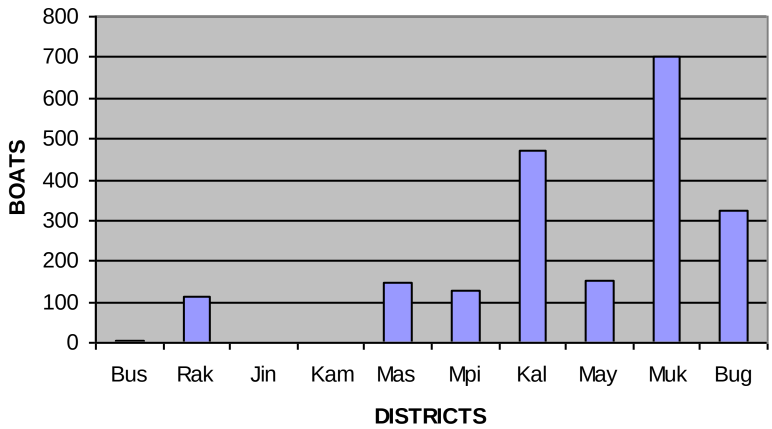

Figure 4. Outboard propulsion

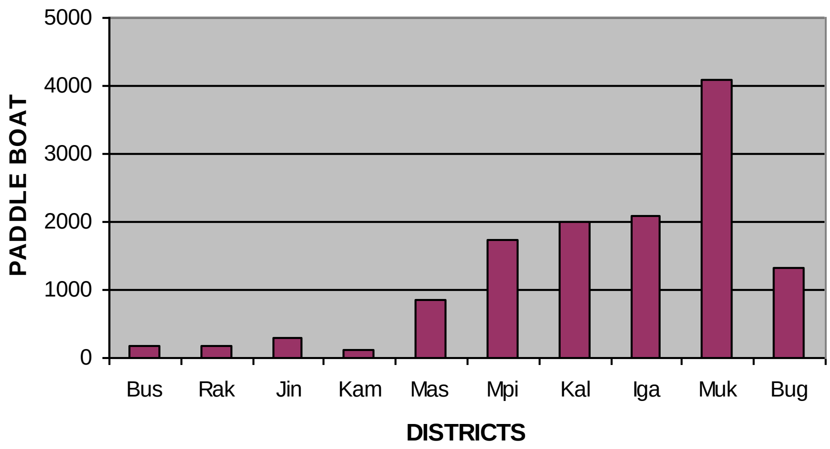

Figure 5. Propulsion by paddles

Percentage paddled within districts

Figure 6 shows within-district distribution of paddled boats as follows. Jinja (100%), Kampala (99%), Busia (97.7%), Mayuge (86.2%), Kalangala (80.8%), Mukono (84.13%), Rakai (60.4%), Bugiri (64.8%).

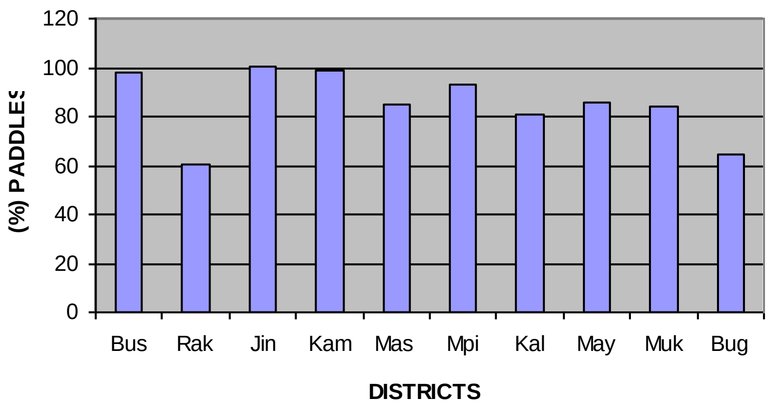

Figure 6. Means of propulsion within districts (%) Paddles

Boats using sails

Figure 7 shows the distribution of boats using sails by district. Total sails on lake were only 665. This made (4.3%) of national total fishing canoes. Percentage distribution of sails within district were spread out as follows: Bugiri (19.4%), Mayuge (7.6%), Mukono (1.5%) and Mpigi (0.27%).

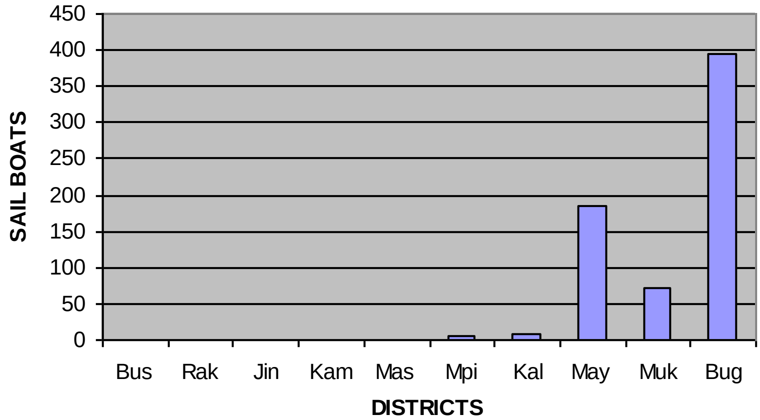

Figure 7. Propulsion by sails

Percentage outboard engine distribution within districts

The Percentage distribution of outboard engines within districts is depicted in Figure 8. It is as follows: Rakai (39.4%), Kalangala (18.95%), Bugiri (15.8%), Mukono (14.4%), Masaka (14.6%).

Gillnets

Figure 9 displays histograms of boat types and composition of gillnets sizes they carry. It was found out that Ssese boats using sails and motorized engines are appropriate for fishing since they carry higher mesh gillnets of >5 inches.

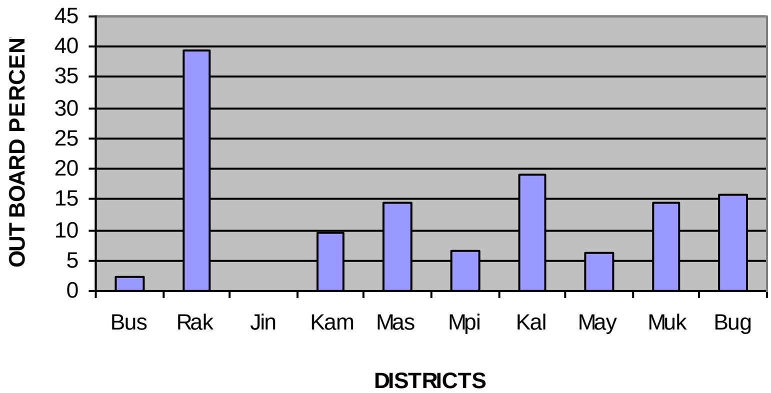

Figure 8 Means of propulsion within districts (%) outboard

Road network

A total of 127(23%) fish landings reported having an all weather road network in the vicinity.

Power network

Only 16 (3.6%) landings reported having power at/or very near source.

Survey costs (millions UGX)

Total survey costs	62,939,650
Conducting Frame Survey	28,645,250
Data processing	6,869,400
Printing Report	12,425,000
Training (LVFRP)	15,000,000

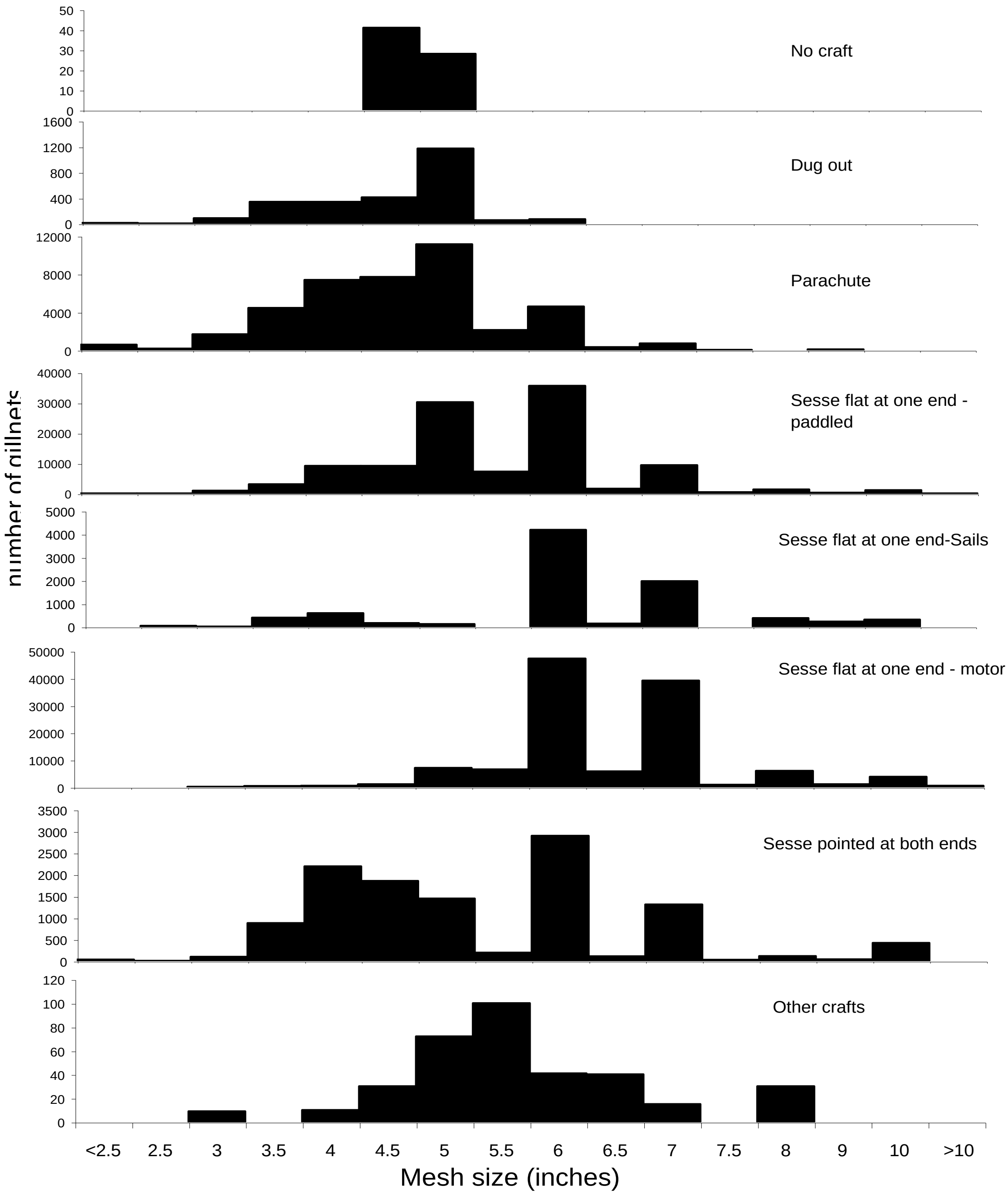

Figure 9. Gillnet mesh size composition in boats of different types in the Uganda sector of Lake Victoria

Discussion

Frame Survey 2000 was carried out on lake Victoria after a previous one done way back in 1990 by the Fisheries Department. It is important to compare the shift in fishing effort and entry into the lake Victoria fishery: We note a substantial entry into the fishery in the past ten years. There were about 25,000 fishers by 1990. Now there are 34, 889 fishermen over the lake. This is an increase by 28.3% in past ten years. Compared to 1970, there has occurred an increase of 69.7% entry into lake Victoria fisheries.

There were 8,674 fishing boats in the 1990 survey. Today there are 15,544 fishing boats. This now represents a double increase in effort in the past ten years. This roughly represents a rate of entry of 700 vessels per year on lake Victoria.

Nationally, canoe motorisation is at about 14%. There is a high incidence of entry of fishers but with a low capacity to exploit the offshore fishery efficiently. The highest percentage of boats (82.6%) use paddles. Only 4.3% use sails. The use of sails has been gaining popularity in eastern districts but has not gained ground in the rest of the lake due to inadequate knowledge to use it. It is a cost effective method compared to use of engines for fishing.

Infrastructure development at fish landings has remained rudimentary since time immemorial. Access roads are wanting. Only 127 landings (23%) of all landings reported an access road; Power is also wanting. Only 16 landings are linked to power. These are mostly near urban areas. We also note lack of suitable amenities at all fishing villages e.g. all reported cold rooms were non-functional. Overall development is restricted and markets cannot be accessed.

The future of the fishing industry now lies in developing a multi-sectoral approach to development, integration of community, mobilization and empowerment for change in preparation for a new down.

Conclusion

This analysis suggests that there is already high effort on lake a high rate of entry per year. The majority of boats use paddles. These boats (which are 82.6%) in the in fishery carry fishing gears that are not recommended. It therefore, becomes important start out on a management plan of action that translates into good not only for us a nation but also for sustainability of the fishery itself. There is also need for resources mobilization to empower communities to participate in management. They have proved a viable ally in the area of data collection and need minimal funding compared to previous strategy of using extension staff.

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Indigenous knowledge and Baseline Data survey on Fish Breeding areas and seasons in Lake Victoria – Kenya

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Abstract

Available baseline data and indigenous knowledge on Lake Victoria fisheries were used to identify potential fish breeding areas and seasons for subsequent scientific verification, demarcation and closure. River mouths, sheltered bays and wetlands featured as the major fish breeding grounds for the majority of the fishes. Two peak rainy seasons of March to August and October to December were found to be the major fish breeding seasons for the different species of fishes of Lake Victoria. The evidence given by the fishers to support the identified breeding areas/seasons particularly from indigenous knowledge include the presence of many fish fry, fingerlings and eggs in the mouths of the fish (mouth-brooders). The size at which fish matures and fecundity was well documented by baseline data. The fisher community has a wealth of knowledge that is useful in the identification of fish breeding (closed) areas and seasons, but the knowledge is clouded by socio-economic considerations. This study has resulted in the gazettement of 98 fish breeding grounds and declaration of breeding seasons between 1st April and 31st. July of each year in the Kenya waters of Lake Victoria vide the Kenya Gazette Notice No. 7565 of 9th. November, 2001.

Keyword: Baseline data, indigenous knowledge, breeding areas, breeding seasons, and closed areas/seasons.

Introduction

The main objective of the closed areas/season activities were to identify, demarcate and gazette fish breeding areas and designate the breeding seasons. This sub-component falls under the closed areas /seasons and the strengthening of enforcement, being undertaken by Fisheries Department (Ministry of Agriculture and Rural Development), under the Lake Victoria Environmental Management Programme (LVEMP). The stakeholders meeting under the sub-component recognized the need to carry out the following activities in order to achieve the desired objectives:

i) Compilation of a bibliography on Lake Victoria
ii) Compilation and availing baseline data
iii) Acquire information on indigenous knowledge
iv) Carry out scientific verification of proposed designated closed areas and seasons.

Part i to iii have been completed. This report covers part ii and iii that involves the compilation of baseline data and indigenous knowledge survey on the fish species, their distribution, breeding areas, breeding seasons, fecundity, growth and related meteorological data.

Materials and method

The baseline data compiled in this report was obtained from published material and raw data from various libraries, individuals and organization in Kisumu, Nairobi and Eldoret. Copies

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of the documents were made and relevant information extracted on various species, its area or extent of distribution in the Kenya side of Lake Victoria basin. Fish breeding grounds, seasons, fecundity and country from which the information was obtained and details of the document, whether published or oral were noted. To address the issue of season comprehensively, some data were acquired on monthly average rainfall patterns from 1950 to 2000 and estimated river discharge for the major effluent rivers draining the Kenya side of Lake Victoria basin.

Indigenous knowledge on breeding/closed areas and seasons were obtained from a pre-designed and semi-structured questionnaire administered through the District Fisheries Officers in the Kenya part of the lake. The questionnaires were floated to the fishermen and stakeholders between 1998 and 2000. Part A of the questionnaire form dealt with demographic characteristic of the fishermen; Part B and part C of the form dealt with knowledge on fish breeding grounds and closed season respectively including opinion of the fishermen on designating the identified areas as closed areas/seasons to fishing activities.

Results

Baseline Data

a)Fish Distribution

A variety of fish species were distributed over the basin in the main lake and in rivers. *Bagrus docmac* was specifically caught between 4 and 79 m in bottom trawl surveys in the 1970s and in the 1980s. Limited data was available on the present distribution or its abundance in the lake. The indigenous knowledge results came out with the fact that the fish have moved from the main lake to the fringes of the main lake, bays, river mouths, river courses and satellite lakes.

Clarias gariepinus was also caught in the bottom trawls between 4 and 79 m in the 1970s. Surveys in the 1980s and 1990s indicate that the fish is also found in effluent rivers, especially in the Sondu-Miriu system. The *C. gariepinus* is presumed to escape the open lake dominated by predatory *L. niloticus*.

The *Haplochromis spp.* were reported between 4m and 79m depth in the 1970s. Similar work during the same period in Kenya showed that different groups were found at different depths ranging from 4m to 9m and from 30 to 50m (Mwalo, 1994). *Oreochromis esculentus* was found between 4-50m depth (Bergstrand & Cordone, 1971) while *Oreochromis niloticus* has a wider distribution in >20 m depth and *Oreochromis*

Table 1: The distribution of different species in Lake Victoria basin obtained from published data by country and by source of information.

Species	**Code**	**Distribution**	**Country**	**Authority**
Bagrus docmac	5	4-79 m		Bergstrand & Cordone, 1971
Bagrus docmac	5	Ubiquitous	Kenya	Lowe-McConnell, 1987
Clarias gariepinus	7	4-79 m		Bergstrand & Cordone, 1971
Clarias gariepinus	7	Sondu-Miriu	Kenya	Lung'ayia, 1994
Clarias gariepinus	7	Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Haplochromis spp.	10	10-19m 59% of 74 groups	Kenya	Mwalo, 1994
Haplochromis spp.	10	20-29m 68% of 74 groups	Kenya	Mwalo, 1994
Haplochromis spp.	10	30-49m 30% of 74 groups	Kenya	Mwalo, 1994
Haplochromis spp.	10	4-79 m		Bergstrand & Cordone, 1971
Haplochromis spp.	10	4-9m 80% of 74 groups	Kenya	Mwalo, 1994
Haplochromis spp.	10	50-59m 10% of 74 groups	Kenya	Mwalo, 1994
Lates niloticus	13	0.92% <30 m	Uganda	Okaronon, 1994
Oreochromis esculentus	16	4-50 m		Bergstrand & Cordone, 1971
Oreochromis niloticus	18	<20 m	Uganda	Okaronon, 1994
Oreochromis niloticus	18	Nyanza Gulf	Kenya	Lunga'yia, 1994b
Oreochromis niloticus	18	Nyanza Gulf		Lowe-McConnell, 1955
Oreochromis variabilis	19	Inshore/exposed/shoaling for 17-20 cm		Fryer, 1961
Oreochromis variabilis	19	Inshore/exposed/shoals for 8-17 cm		Fryer, 1961
Oreochromis variabilis	19	Rocky <0.5 m for 30-45 mm		Fryer, 1961
Oreochromis variabilis	19	Rocky <5 cm for 15-30 mm		Fryer, 1961
Oreochromis variabilis	19	Rocky/Vegetation <0.5 m for 4.5 - 6 cm		Fryer, 1961
Oreochromis variabilis	19	Variable/rocky/sandy fro 20-28 cm		Fryer, 1961
Protopterus aethiopicus	22	4-60 m		Bergstrand & Cordone, 1971
Rastrineobola argentea	23	Bottom (Day)/Surface (Night)	Uganda	Wandera, 1993
Schilbe intermedius	24	Nyando		Omondi & Ogari, 1994
Schilbe intermedius	24	Sondu-Miriu		Ochumba & Manyala, 1992
Schilbe intermedius	24	Nyanza Gulf	Kenya	Rinne & Wanjala, 1980
Synodontis victoriae	25	4-79 m		Bergstrand & Cordone, 1971
Synodontis victoriae	25	Sondu-Miriu	Kenya	Ochumba & Manyala, 1982
Synodontis afrofischeri		Sondu-Miriu	Kenya	Ochumba & Manyala, 1982
Xenoclarias	26	>50m	Kenya/Uganda	Rinne, 1980
Xenoclarias eupagon	27	>40 m depth	Kenya, Uganda, Tanzania	Rinne, 1980

variabilis seem to be restricted to the inshore areas over rocky, vegetated, sandy and exposed areas.

Schilbe intermedius, Synodontis victoriae and *Synodontis afrofischeri* have been reported in the Sondu-Miriu in the recent past but was common in the main lake in the 1980s (Ochumba & Manyala, 1982) while *Xenolcarias spp.* was mainly found below 40 m depth in both Kenya, Uganda and Tanzania parts of Lake Victoria (Rinne, 1980). The general distribution of the species is shown in Table 1.

b) Breeding areas/seasons

Barbus altianalis and *Clarias gariepinus* breeds 10 Km upstream the Sondu-Miriu river while *Labeo victorianus, Oreochromis variabilis, Synodontis victoriae, Synodontis afrofischeri* and *Oreochromis niloticus* breeds 8 km up the same river. *Schilbe intermedius* breeds some 9 km up the Sondu-Miriu and also breeds in River Nyando (Ochumba & Manyala, 1992; Omondi & Ogari 1994). The results tend to confirm the observed high prevalence of juveniles and berried fish at the river mouths/estuaries. *Gnathonemus longiberbis, Hippopotomyrus grahami, Marcusenius victoriae, Mormyrus kannume, Petrocephalus catostoma* and *Pollymyrus nigricans* breeds in the effluent rivers of Lake Victoria, 2 - 24 km upstream (Table 2).

Protopterus aethiopicus breed in Lake Victoria in marginal swamp, *Cyperus papyrus* swamp, semi-aquatic grass and specifically in Nyando and Sondu-Miriu floodplains (Pabari, 1998). *Oreochromis variabilis* breeds in the fringe forming 15 m from shoreline (Ochumba & Manyala, 1992) while *Oreochromis niloticus* breeds at depths of 3-9 m in sandy areas as well as in offshore areas (Ogari, 1994). *Oreochromis leucostictus* breeds in inshore areas through out the year (LoweMconnell, 1987) while several groups of *Haplochromis spp.* breed in the littoral and sub-littoral areas (Witte, 1981; Lowe Mconnell, 1987). *Lates niloticus* is thought to breed in the pelagic zone of Lake Victoria (Acere, 1987). *Bagrus docmac* and *Clarias gariepinus* are thought to breed in Lake Victoria but the exact breeding areas are not specified. It is possible that this happened before the upsurge of *L. niloticus*. The information extracted from the questionnaire, indicate that the two species move to shallow waters and rivers to breed (Table 2)**.**

c) Size at maturity

The size at which more than 50% of sample population shows maturity is shown in Table 3 for both females and males. It should be noted that some fish species for example *Protopterus aethiopicus* mature at an earlier size than previously experienced. For example, *Protopterus aethiopi*cus was earlier recorded to mature at about 98cm (Okedi, 1971). Current records on the same fish indicate that they now mature at 35 cm (Pabari, 1998).

d) Fecundity

Fecundity of the fish species found within the Lake Victoria basin is shown in Table 4. *L. niloticus* has been recorded to produce as much as six million eggs (Ogutu-Ohwayo).

Table 2: The breeding season and areas in Lake Victoria Basin

Species	Code	Breeding Season	Breeding area	Country	Authority
Bagrus docmac	5	Protracted/Peaks in Jan/August	Lake Victoria		Lowe-McConnell, 1987
Barbus altianalis	6	Mar-Apr/Aug-Sep/Oct-Nov	10 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Clarias gariepinus	7	April-June/Sept-Oct		Kenya	Lung'ayia, 1994a
Clarias gariepinus	7	Feb-Aug	10 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Clarias gariepinus	7	Protracted/Peaks in Jan/August	Lake Victoria		Lowe-McConnell, 1987
Clarias gariepinus	7	Sep-Oct	Sondu-Miriu	Kenya	Lung'ayia, 1994a
Gnathonemus longiberbis	8	April-May/Sept-Dec	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Haplochromis spp.	10	End of rainy seasons	Littoral/Sub-littoral	Tanzania	Witte, 1981
Hippopotomyrus grahami	11	April-May/Sept-Dec	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Labeo victorianus	12	Jan-Apr/Sep-Nov	8 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Lates niloticus	13		Pelagic zone		Acere, 1987
Marcusenius victoriae	14	April-May/Sept-Dec	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Mormyrus kannume	15	Throughout the year	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Oreochromis esculentus	16	April-May/Sept-Dec			Lowe-McConnell, 1987
Oreochromis esculentus	16	Sep-May			Greenwood, 1966
Oreochromis leucostictus	17	October			Ogari, 19??
Oreochromis leucostictus	17	Throughout the year	Inshore		Lowe-McConnell, 1987
Oreochromis niloticus	18	Apr-Jun/Sep-Dec	9 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Oreochromis niloticus	18		3-9 m sandy areas		Ogari, 19??
Oreochromis niloticus	18		Nyanza Gulf	Kenya	Lung'ayia, 1994b
Oreochromis niloticus	18		Offshore		Lowe-McConnell, 1987
Oreochromis variabilis	19	Jun-Aug	8 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Oreochromis variabilis	19		15 m from shoreline		Fryer, 1961
Petrocephalus catostoma	20	April-May/Sept-Dec	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Pollymyrus nigricans	21	April-May/Sept-Dec	Effluent rivers, 2 - 24 km		Lowe-McConnell, 1987
Protopterus aethiopicus	22	Apr-May/Sep-Nov	Marginal swamp		Greenwood, 1966
Protopterus aethiopicus	22	July-Aug/Feb	Nyando floodplains	Kenya	Pabari, 1998
Protopterus aethiopicus	22		Marginal swamps	Uganda	Greenwood, 1966
Protopterus aethiopicus	22		Marginal swamps	Uganda	Copley, 1941
Protopterus aethiopicus	22		Papyrus swamp		Greenwood, 1966

Protopterus aethiopicus	22		Papyrus swamps	Uganda	Greenwood, 1966
Protopterus aethiopicus	22		Semi-aquatic grass	Uganda	Greenwood, 1966
Rastrineobola argentea	23	Feb-Mar		Tanzania	Wadera & Wanink, 1995
Rastrineobola argentea	23	Oct-Nov		Uganda	Wandera & Wanink, 1995
Schilbe intermedius	24	Protracted/Peaks in Jan/August			Lowe-McConnell, 1987
Schilbe intermedius	24	Rainy season	Sondu-Miriu	Kenya	Ojwang & Muli, 1993
Schilbe intermedius	24	Sep-Apr	9 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Schilbe intermedius	24		Nyando	Kenya	Omondi & Ogari, 1994
Synodontis victoriae	25	Apr-Jun/Oct-Dec	8 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Synodontis afrofischeri	25	Jan-Apr/Jul-Sep	8 Km Sondu-Miriu	Kenya	Ochumba & Manyala, 1992
Synodontis victoriae	25	Protracted/Peaks in Jan/August			Lowe-McConnell, 1987
Tilapia zillii	25	Throughout the year			Lowe-McConnell, 1987
Xenoclarias	26	Jan-Mar		Kenya/Uganda	Rinne, 1980
Xenoclarias eupagon	27	Jan-Mar/Dec		Kenya, Uganda,Tanzania	Rinne, 1980

1988). Another report indicates that it produces as much as eleven million eggs (Lowe Mc-Connell, 1987). The cichlid family of fishes are likely to surfer most because most of them produce few eggs, that is, in terms of hundreds and even tens as in the case of *Haplochromis spp.* (Lowe Mc-Connell, 1985, 1987, Mwalo, 1994). This is not healthy for their survival. Protopterus aethiopicus was reported to produce eggs in terms of 8000 (Okedi, 1971). The same fish has been recorded recently to produce fish in terms of hundreds (Pabari, 1998). Generally, it is apparent that the fish fertility may be reducing.

Table 3: Size at maturity of different male and female fish species by different authors separated by country

Species	**Code**	**Maturity (Females)**	**Maturity (Males)**	**Country**	**Authority**
Barbus altianalis	6	7.0 cm SL	7.0 cm SL	Kenya	Ochumba & Manyala, 1992
Clarias gariepinus	7	21 cm TL	21 cm TL	Kenya	Lung'ayia, 1994a
Clarias gariepinus	7	21.1 cm SL	14.1 cm SL	Kenya	Ochumba & Manyala, 1992
Clarias gariepinus	7	41- 45 cm	41 - 45 cm	Kenya	Owiti & Dadzie, 1989
Haplochromis spp.	10	93 mm	85 mm	Kenya	Mwalo, 1994
Haplochromis spp.	10	93 mm	89 mm	Kenya	Mainga, 1994
Labeo victorianus	12	15.1 cm SL	11.1 cm SL	Kenya	Ochumba & Manyala, 1992
Lates niloticus	13	60 - 95 cm	50 - 65 cm	Uganda	Ogutu-Ohwayo, 1988
Lates niloticus	13	67 cm	53 cm		Acere, 1987
Lates niloticus	13	80 - 85 cm	50 - 55 cm	Kenya	Hughes, 1992
Oreochromis esculentus	16	25-26 cm TL	25-26 cm TL		Greenwood, 1967
Oreochromis niloticus	18	13 cm	13 cm		Ogari, 19??
Oreochromis niloticus	18	15.8 cm TL	15.5 cm TL		Ogari, 19??
Oreochromis niloticus	18	29.7 cm TL	24.5 cm TL	Kenya	Dache, 1994
Oreochromis niloticus	18	7.1 cm SL		Kenya	Ochumba & Manyala, 1992
Oreochromis variabilis	19	7.1 cm SL		Kenya	Ochumba & Manyala, 1992
Protopterus aethiopicus	22	35 cm	35 cm	Kenya	Pabari, 1998
Protopterus aethiopicus	22	96 cm TL	96 cm TL		Okedi, 1971
Rastrineobola argentea	23	36 mm SL	34 mm SL	Kenya	Manyala, 1995b
Rastrineobola argentea	23	44 mm SL	44 mm SL	Uganda	Wandera, 1988
Schilbe intermedius	24	12.1 cm SL	12.1 cm SL	Kenya	Ochumba & Manyala, 1992
Schilbe intermedius	24	17.8 cm	13.6 cm	Kenya	Ojwang & Muli, 1993
Synodontis afrofischeri	25	10.1 cm SL	10.1 cm SL	Kenya	Ochumba & Manyala, 1992
Synodontis victoriae	25	8.1 cm SL	10.1 cm SL	Kenya	Ochumba & Manyala, 1992
Xenoclarias eupagon	27	14-16 cm		Kenya, Uganda, Tanzania	Rinne, 1980

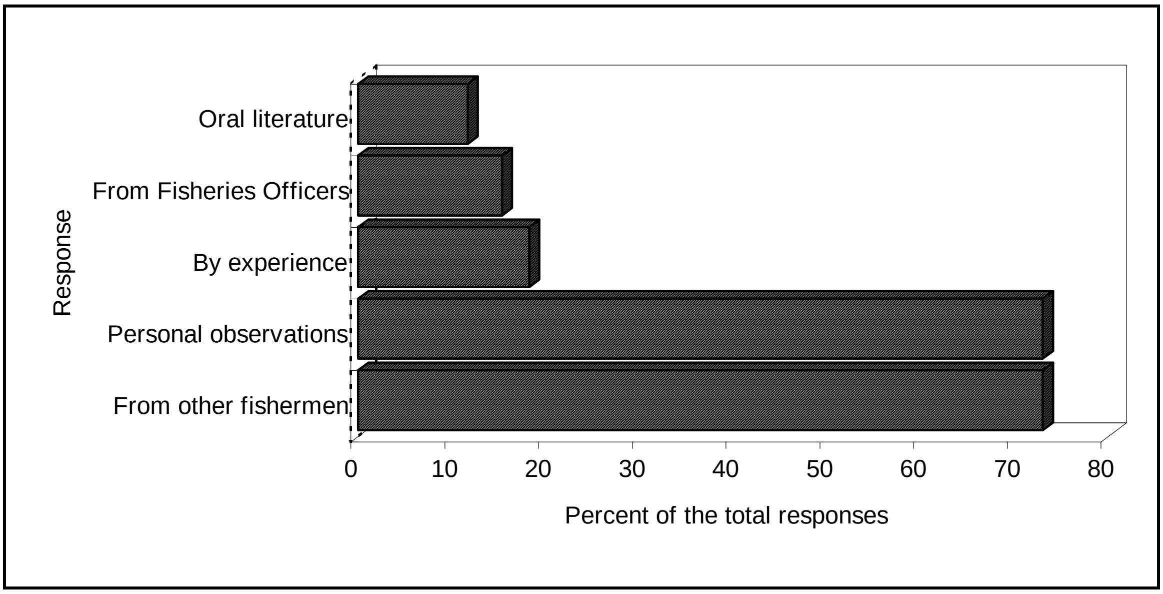
Indigenous knowledge survey

a) Fish breeding areas/seasons

A number of fish species were identified by the respondents to be breeding in the areas. Among the species mentioned were *Oreochromis niloticus* (L.) or generally tilapia featured in 85% of the respondents while *Clarias gariepinus* featured in 50% of the respondents respectively. The lungfish (*Protopterus aethiopicus* and *Lates niloticus* featured in about 38% and 47% of the answers given by the respondents. The rest of the species featured in less than 25% of the answers obtained from the respondents.

b) Sources of information for breeding areas/seasons

More than 70% of the respondents obtained information about the breeding grounds from fellow fishermen. All other sources of information featured less than 20% in all the respondents in (Fig. 1). The evidences given for designating the mentioned areas as breeding grounds were based on the presence of many larvae/juveniles in the catches in more than 50% of the respondents (Fig. 2). Other evidences given include the skewed sex ratio with more females than males (>40%), fish with larvae in their mouths, especially some cichlids (38%) while other reasons were given by less than 35% of the respondents.



Fig, 1: Relative importance of the sources of information for breeding seasons.

c) Designation of breeding (closed) areas

The results of designating the breeding grounds as closed areas indicate that more than 50% of the respondents think that these areas should not be designated as closed areas while only 25% think that they should be closed for fishing (Fig. 3). Majority of the respondents (83%) also thinks that these areas should be closed for fishing throughout the year and less than 5% think they should not be closed throughout the year (Fig. 4). Also, after identifying the breeding areas, 56 out of 137 respondents still opposed closing these areas as breeding

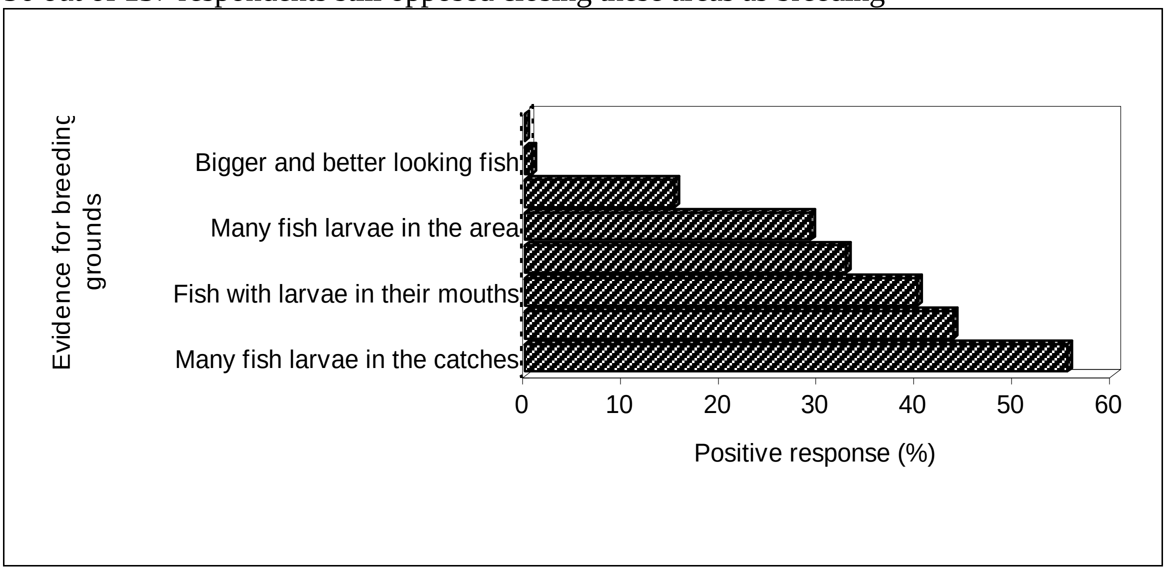


Fig 2: Relative % frequency of evidences given by the respondents in favour of breeding grounds.

grounds (Table 5). An analysis of the reasons given for opposing closure of these areas as breeding grounds, indicate that the respondents gave more socio-economic considerations than socio-cultural or biological factors. This situation signifies a breakdown of traditional norms of sustainable fisheries resource utilization and conservation.

The 98 localities areas identified in Table 7 were gazetted as fish breeding areas, Gazette Notice No. 7565 of 9th November 2001 and the notice became effective on 1st July 2001.

Those who think that these areas should not be closed for fishing throughout the year, gave varying reasons which range from the knowledge of the breeding months to loss of livelihood for fishermen (Table 6). From the analysis, the following are some of the identified major fish breeding areas ; Obolobolo, Samba wetlands in Homa Bay, Kusa Bay, Osiri, Arongo/Kagwel, Tako, Hippo point, Kabudho, Minara Island, Ndere Island, Ogenya, Matara Bay, Kadimo, Karugu Bay, Bays, Swamps, Flood plains and all river mouths (Table 7).

d) Breeding (closed) seasons

The respondents identified the peak breeding periods to be April/May and July. Most respondents did not specify the peak (months) of the fish breeding periods and the breeding months were therefore based on the cumulative responses for each month for 8 levels of priority (Fig. 5). There were several species identified by the respondents to be breeding during the breeding period. Tilapia (*Oreochromis niloticus*) featured in more than 70% of the total responses followed by *Lates niloticus* and *Clarias gariepinus* (40% each) (Fig. 6). Relative importance of evidences given by respondents for breeding seasons ranged from fish gravid fish to preponderance of fish larvae in the area (Fig. 7)

Rainfall data

Monthly rainfall data averaged from 1950 to 2000 indicate that there are two peak rainfall seasons falling between March and May and another one between October and December (Fig. 8). Indigenous knowledge seems to support synchronized movement of fish to breed upstream for anadromous fish during peak rainy seasons.

Table 4: Fecundity of different species by country

Species	Code	Fecundity	Country	Authority
Brycinus dentex	1	24800 - 27800		Lowe-McConnell, 1987
Brycinus leuciscus	2	1000 - 4000		Lowe-McConnell, 1987
Brycinus macrophthalmas	3	10000		Lowe-McConnell, 1987
Brycinus nurse	4	17000		Lowe-McConnell, 1987
Clarias gariepinus	7	7966-229648	Kenya	Owiti & Dadzie, 1989
Gnathonemus longiberbis	9	502 - 14624		Lowe-McConnell, 1987
Haplochromis spp.	10	84	Kenya	Mainga, 1994
Haplochromis spp.	10	78	Kenya	Mwalo, 1994
Hippopotomyrus grahami	11	248 - 5229		Lowe-McConnell, 1987
Labeo victorianus	12	40133		Lowe-McConnell, 1987
Lates niloticus	13	1104700 - 11790000		Lowe-McConnell, 1987
Lates niloticus	13	6000000	Uganda	Ogutu-Ohwayo, 1988
Marcusenius victoriae	14	846 - 16748		Lowe-McConnell, 1987
Mormyrus kannume	15	1393 - 17369		Lowe-McConnell, 1987

Oreochromis esculentus	16	324 - 1672		Lowe-McConnell, 1987
Oreochromis leucostictus	17	56 - 498		Lowe-McConnell, 1987
Oreochromis leucostictus	17	99 - 950		Lowe-McConnell, 1985
Oreochromis niloticus	18	340 - 3706		Lowe-McConnell, 1985
Oreochromis niloticus	18	864 - 6316	Kenya	Lung'ayia, 1994b
Oreochromis variabilis	19	23 - 496		Lowe-McConnell, 1985
Petrocephalus catostoma	20	116 - 1015		Lowe-McConnell, 1987
Polymyrus nigricans	21	206 - 739		Lowe-McConnell, 1987
Protopterus aethiopicus	22	8960		Okedi, 1971
Protopterus aethiopicus	22	1700 - 2300		Lowe-McConnell, 1987
Protopterus aethiopicus	22	218 - 542	Kenya	Pabari, 1998
Rastrineobola argentea	23	1800 - 3500	Kenya	Manyala, 1995b
Tilapia zillii	25	1000 - 5711		Lowe-McConnell, 1985
Xenoclarias eupagon	27	744-1357	Kenya, Uganda, Tanzania	Rinne, 1980

River Discharge

The average monthly river discharge for major river basin show that the highest period of discharge shown by River Nzoia April to December but only in May/June and September for River Sondu-Miriu (Fig. 9). River Yala experiences peak discharge from May to October while River Kuja-Migori has experiences only one peak during April/May but the their maximum discharge is sometimes less than half for those of River Nzoia and

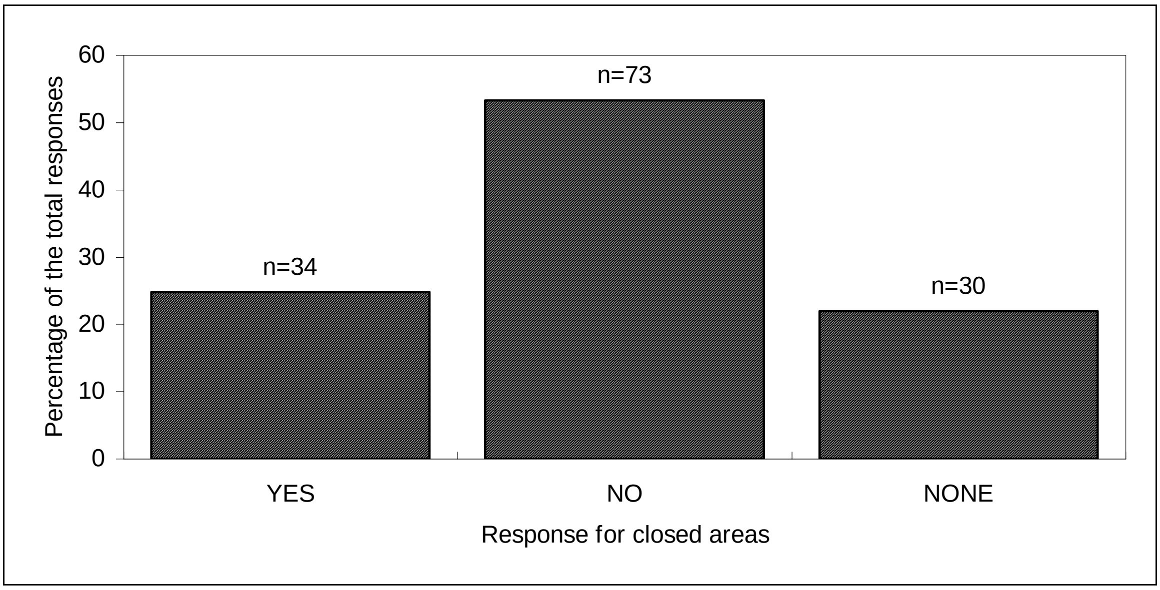


Fig. 3: Opinion by respondents about designating the identified breeding areas as closed areas

Sondu-Miriu (1000 m^3s^{-1}). River Nyando shows the least discharge volume but with peaks in April/May and August/September. More diversified fish species have been recorded in River Miriu than in River Nyando and this means that river discharge is also vital for diversity of fish species.

Table 5: Opinion given by the respondents for non-conformation to identified closed seasons.

REASONS	TOTAL	YES	NO	NONE
No reason given	62	32	6	24
Close during breeding months	50	1	47	2

Close during breeding seasons	2	1	1	
Fishermen loose their livelihood	13	11	2	
Fishermen get more fish	4	4		
No undersized fish caught at times	1	1		
Fishery should be open from August	1	1		
Enough fish since 1950s	1	1		
Throughout the year for breeding	1	1		
Only appropriate gear should be used	2	2		
TOTAL	137	55	56	26

Discussion

Data on the distribution of many species in Lake Victoria basin is scanty (Table 1). However, some of the information provided in published literature gives a starting point on which areas and seasons to target for closure. This information can only be used with

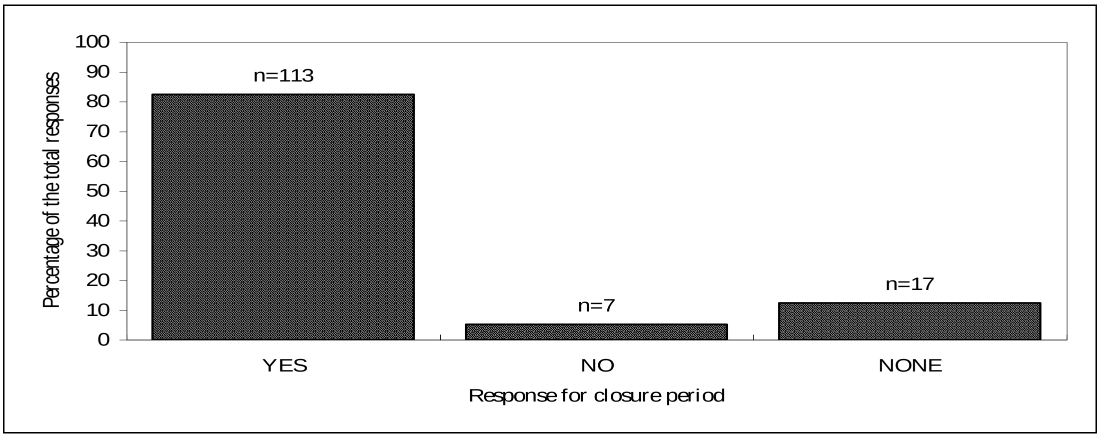


Fig 4: Opinion about having a closed season throughout the year as given by the respondents

the indigenous knowledge of the breeding areas since the geographical extent of the species is not necessarily an indication of the exact breeding areas. Very clear stratification of the breeding areas/seasons was observed for the haplochromiine cichlids and tilapiines, *Rastrineobola argentea* and *Lates niloticus*. Incidentally, these species form the major fisheries of Lake Victoria at the moment and are possible the primary candidates to be considered for protected areas. The next in line would be the riverine (potamadromous) species of which there is very scanty data apart from the Sondu-Miriu river.

Table 6: Information on opinion why there should not be a closed season for fishing as given by respondents.

REASON	TOTAL	YES	NO
No information given	1		1
Fencing of breeding grounds	104	102	2
Loss of fishermen's livelihood	5		5
Prohibit undersized nets	10		1
Set nets away from the shoreline	15		1
Use large mesh sizes	2	2	
	137	104	10

On the published data for the breeding areas and seasons of different fish species in Lake Victoria basin, it is clear that available information is inadequate for some species, general for others and quite detailed for some species. This information therefore provides basic guideline on which closed areas can be delineated. One of the obvious target areas for closure includes the major river estuaries. It is clear from the information available from Sondu-Miriu that the riverine system provides a major breeding ground for many fish species during some periods of the year. Many species breed from April to June and from September to October. There are also other species which show peak breeding periods during the other months of the year. These variations are a possible reflection of the impact of local variations in the river inflows from different drainage basins in the Lake Victoria catchment. The implication for observation in the Sondu-Miriu can be extended to the other major river basins but the peak periods of discharge are not similar for all the rivers. There seem to be remarkable local monthly variations (Table 2). The rainfall patterns however seem to suggest two peak rainfall periods within the year.

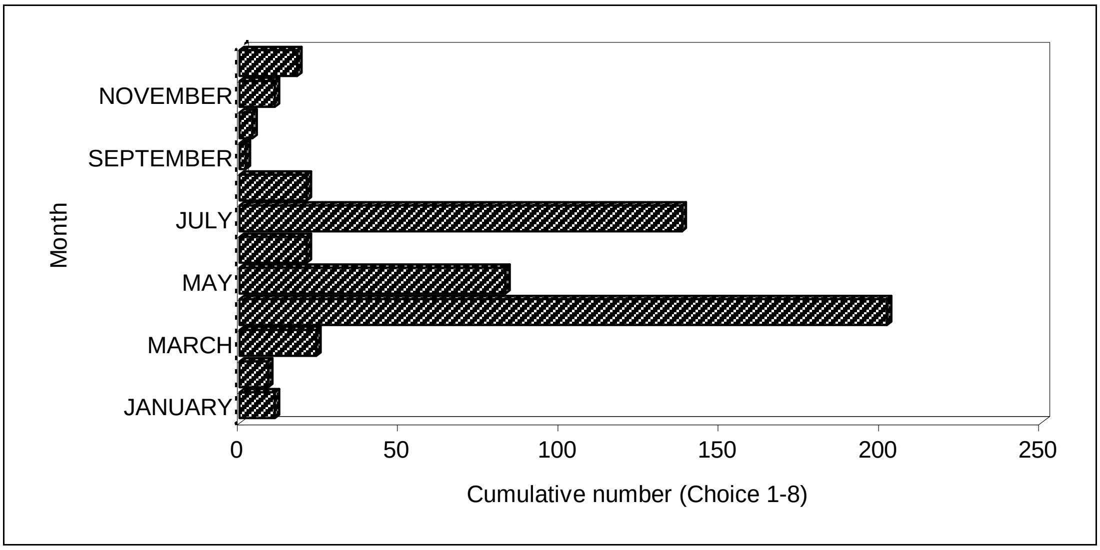


Fig. 5: Breeding seasons identified by the respondents.

The size at maturity for many of the species of fish found in the Lake system seems to have minimal variation among several authors. The mean sizes at maturity from different authors can therefore be used to set or revise the existing minimum mesh size for each of the targeted species of the fishery. There is need for additional data on gear selectivity for this purpose and this type of data may be obtained readily from the present catch assessment survey for Lake Victoria.

Our knowledge on fish fecundity can be useful in estimating expected recruitment for each species. Data on sex ratio and biomass estimate as well as larval mortality or survival can be used to estimate annual recruitment. Fortunately, data on biomass estimate and sex ratio can possibly be obtained from the ongoing Stock Assessment Programme funded by European Union through European Development Fund (EDF). Data on larval survival rates may not be available but estimates could be made based on

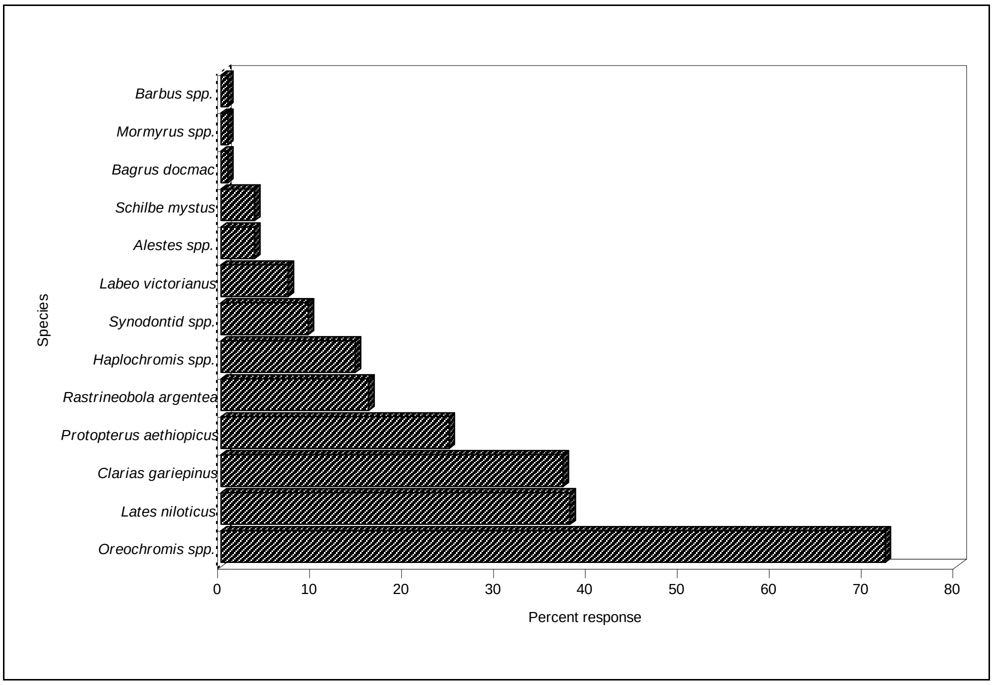


Fig. 6: Relative % frequency of fish species identified to be breeding during the peak breeding seasons.

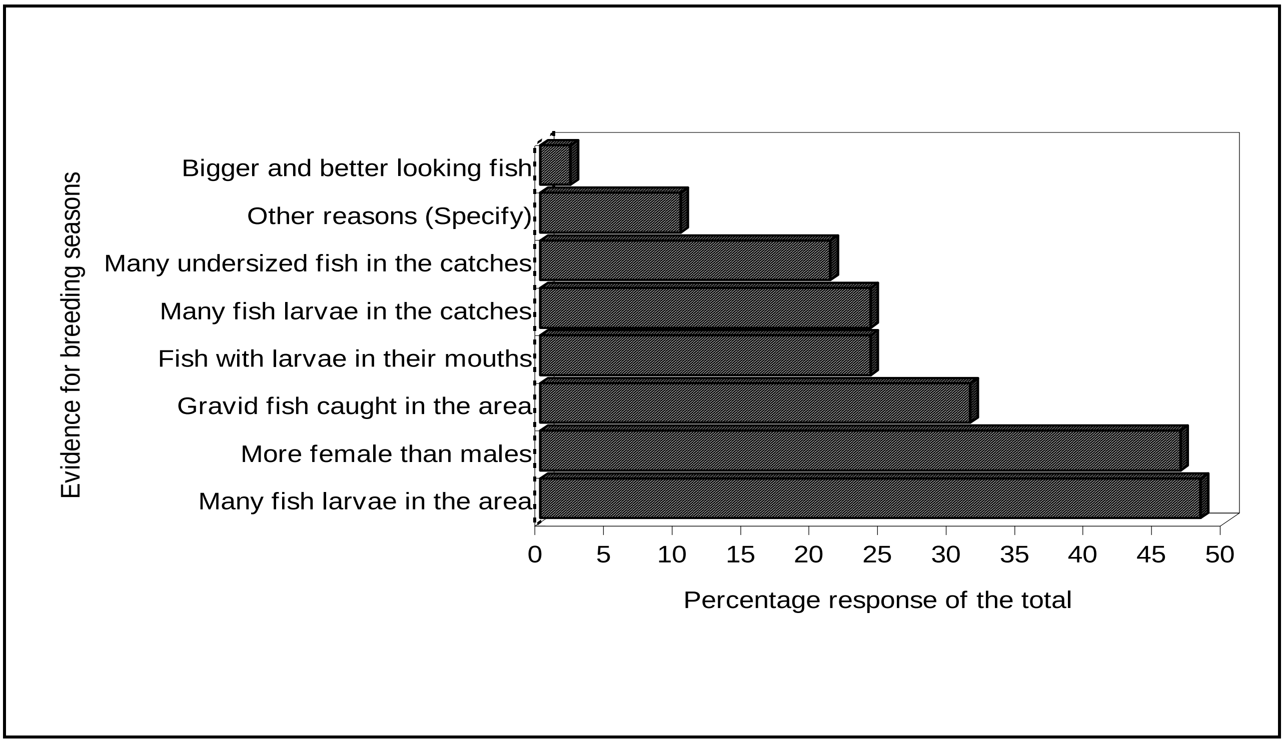


Fig. 7: Relative importance of evidences given by respondents for breeding seasons

analytical procedures. Indigenous Knowledge from the fisher community conforms to the latest findings, which indicates that the distribution of many endemic fish species has changed with the establishment of *Lates niloticus.*

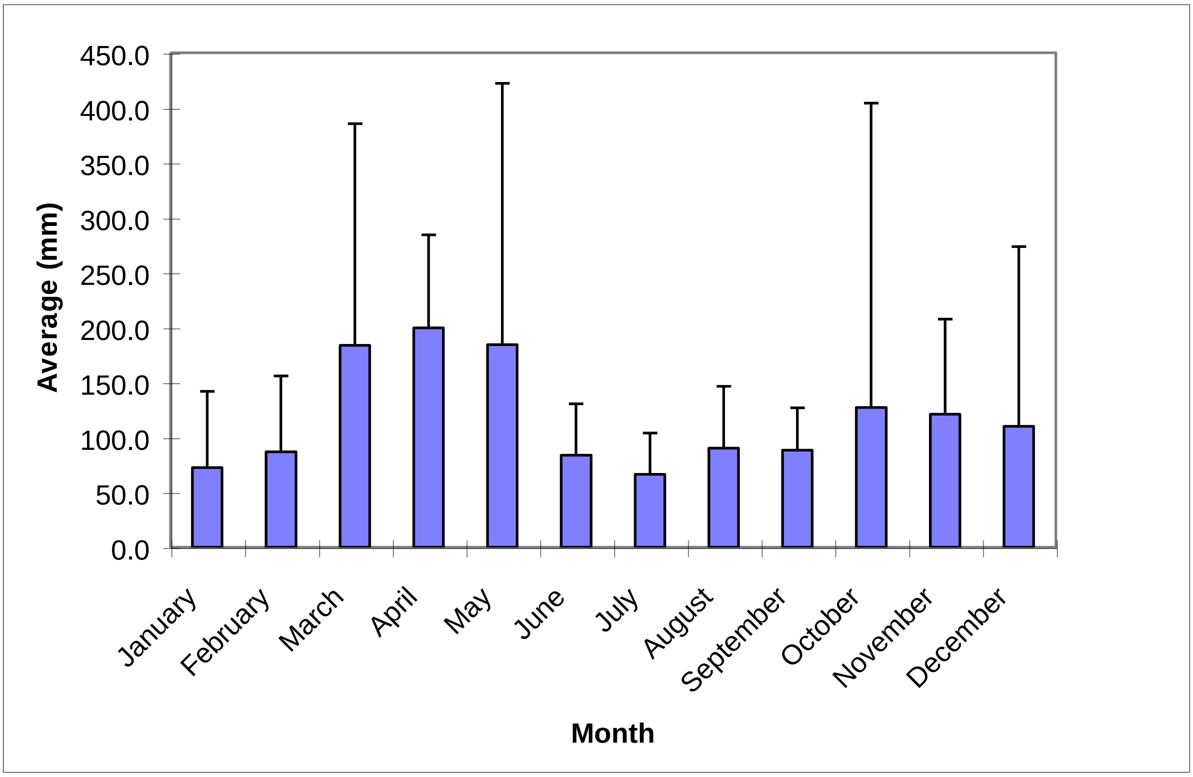


Fig. 8: Mean monthly rainfall averaged from 1950 to 2000 for Lake Victoria region

Recommendations

In view of the foregoing, it is necessary to carry out the following exercises:

1. Carry out ground-truthing exercise using GPS to demarcate the identified breeding areas based on indigenous knowledge and baseline data.
2. Carry out supplementary stock surveys for confirming the proposed areas for closure at the critical times of the year.
3. Obtain the following information from the stock assessment and experimental survey programme:
    a) Species distribution in the lake
    b) Sex ratio for each species
    c) Estimated biomass for each species and Breeding seasons and areas
    d) Determination of Maximum Sustainable Yield and Maximum Economic Yield of various fish species.
4. Hold a workshop to present the final list of the closed areas/seasons to the stakeholders for adoption, subsequent processing and implementation.
5. Work out with the stakeholders an action plan for implementing the closed areas/seasons based on co-management principles

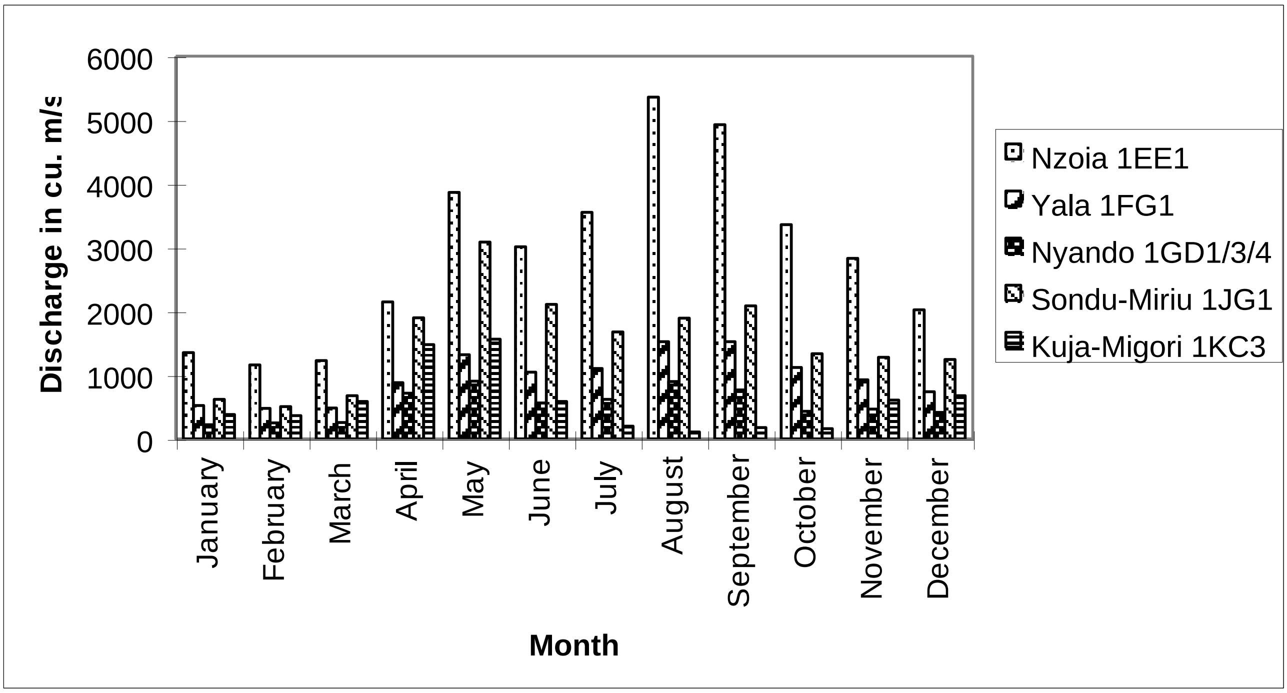


Fig. 9: Mean monthly discharge for the main effluent rivers in the Kenya portion of Lake Victoria.

Table 7: Breeding areas according to respondents interviewed.

District	Area	District	Area
Busia	Sio River mouth	Homa Bay	Obolobolo Bay
	Nzoia River mouth		Rangwena River mouth
	Munaka lagoon		Awach Tende River mouth
	Sango	Suba	Sikri Kamwai
	Ndekwa		Kisaka
	Sisenye		Alero
	Bulwani		Ondao
Bondo	Utonga bay		Gode Ariyo Bay
	Ugambe		Luanda Nyamasare bay
	Nyamwa Bay		Uyoga
	Osindo Bay		Mbita Causeway
	Bao		Kirindo
	Kadolrosa		Kakriga
	Misori area		Kolunga
	Aram zone		Chamaunga Island
	Odola (Kongonga)		Ulugi
	Pesa Odong.o (Uhendo)		Sena
	Ulala area		Nyakweri
	Ludhi		Wakula River mouth

Table 7 contd.

	Madada		Roo
	Rabolo (Ralayo)		Ragwe Bay
	Bur Kokise		Nyamusethi
	Wagusu		Rwanch
Kisumu	Nyando River mouth		Kayola stream mouth Nyamngenyi

	Otiwa-Kaloka Bay		Nyamgondho area
	Obange River mouth		Mungenyi
	Ogenya River mouth		Usulwa
	Oganda River mouth		Kiboe
	Kisat River mouth		Rasira
	Tako	Migori	Kuja River mouth
	Nyandiwa		Migori River mouth
	Abuogo		Ngwena
	Hippo Point		Modi
	Maboko		Aneko
Nyando	Kusa		Ratieny River mouth
	Gehena		Masarura
	Singida		makwach
	Gal stream mouth		Kikongo
	Bala stream mouth		Kower
	Koguta		Tito
	Sondu-Miriu River mouth		Koyondi
Rachuonyo	Sondu-Miriu River mouth		Maguti
	Awach Kibuon River mouth		Mwarache
	Sare Kongoro		Kamambra
	Riat bay		
	Uhuru (Olasi) Bay Rambira		
	In-between Awana and Mitimbili beaches		
	In-between Mariwa and Kobiero beaches		
	In-between Bala Kochoo and Mariwa beaches		
	In-between Lwasi and Remo beaches		
	In-between Bala Rawi and Doho beaches		
	In-between Kanyakiti and Tausi beaches		
	Awach Tende River mouth		

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Investigation of bacteriological quality of smoked fish

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Abstract

The project examined the bacteriological quality of smoked *Lates niloticus* (L) and tilapiine fishes. A total of 45 tilapiine fishes and 44 *Lates niloticus* specimens were analysed. Counts of *Escherichia coli* (E), *Salmonella* sp. detection , and detection of *Vibrio* spp., were undertaken. Samples of smoked fish specimens were collected from selected beaches and markets within the Winam Gulf of Lake Victoria and taken to the laboratory within 24 - 48 hours. *Salmonella enterica* species were found to be absent. *Vibrio* spp. were found to be absent from all the specimens except in the tilapiine fishes from Homa-Bay Pier market. *Escherichia coli* was present in samples from all the markets except Homa-Bay pier market. It was present in samples from Mainuga and Balarawi beaches. Generally, the markets had higher counts of the bacteria than the beaches. The number of bacteria reduced with smoking but increased again with increase in storage period. Sanitary conditions at the beaches and markets should be improved. Likewise, roads to the beaches should be made all-weather roads so that the fish can reach the markets fast. Refrigeration facilities and/or ice should be provided at the landing beaches and at the smoking villages.

Key: *Lates niloticus, Escherichia coli, Salmonella enterica, Vibrio* spp.,

Introduction

Lake Victoria is the source of most of fresh water fish, both for local and export market in Kenya. Kenya earns 7 billion from the sale of fish and fish products (Ikiara, 1999) from the lake. Locally, fish from the lake is marketed as fresh, smoked, sun dried, or fried forms. Currently, Nile perch available to the local market are of poor quality and are rejected by the processing industries. These fish are often putrified. While established quality control measures exist for the export-oriented fish, none exists for the fish consumed locally and this poses a great danger to the health of local consumers.

Even though fish are smoked, the heat supplied might not kill all the pathogens. Smoked fish could be stored satisfactorily for three weeks at 5°C and less than one week at 10°C (Poulter *et al,* 1988). The need for proper refrigeration cannot be over- emphasized. The finished product should not be distributed until it has been properly cooled to 4.2° C or below. Furthermore, because of perishable nature of smoked fish, it is imperative that finished product be maintained in a refrigerated condition at 4.2° C or below until consumed (Otwell *et al.,* 1980). Most food poisoning outbreaks related to smoked fish have been related to abusive storage temperature conditions. In the Lake region, the fish is just kept at room temperatures after the smoking process.

Microorganisms inhabit nearly every niche of the earth and our food is no exception (Pelczar *et al,* 1993). Food items are easily contaminated with microorganisms in nature, during handling and during processing. After contamination, the food serves as a medium for the growth of the microorganisms. If allowed to proliferate, these organisms can change the physical and chemical nature of the food resulting in spoilage. Microorganisms in food may also be responsible for food poisoning and food-borne infections.

In industrialized countries, the smoking of fish is done for the enhancement of flavor and texture. This form of processing sometimes provides little protection against microbiological, enzymatic and chemical deteriorative alterations, and in some instances, smoked foods spoil as readily as non-smoked foods. It is nonetheless used as a method of food preservation in developing countries (Hsu *et al*, 1979). In the Lake region, traditional methods of smoking fish are common. A variety of different woods such as *Accasia seyal, A. Senegal, Balanite egyptica, Syzgium cumnii* among others and dried fish skin are used for smoking. Almost invariably, smoking is done to the fish that is getting spoilt (Ogunja, 1994).

As the fish spoils the price falls and, in most developing countries, even what would normally be considered as heavily spoilt fish would find a market, albeit at a low price (particularly among the poor sectors of the community) (Poulter *et al*, 1988). The species of fish that are usually smoked are *Lates niloticus*, the tilapiines, and *Haplochromis* spp. Although smoking increases shelf life of the fish products, hygienic standards of the fish products before, during and after smoking are suspect (Fisheries dept., 1996). European Union banned fish imports from Kenya in 1996, citing poor sanitary conditions at the landing beaches and lack of refrigeration /icing facilities (Fisheries dept. 1999). Other factors included the use of poisonous substances to catch fish and in poor handling conditions in the landing beaches and at the factories. The European Union ban on fish imports from Kenya negatively impacted on the fishermen and economy of Kenya. The price of a kilogram of Nile Perch dropped from Ksh. 50.00 to Ksh.15.00 (Abila and Jansen, 1997). This eroded the buying power of the people. The ban also led to loss of jobs in the fish processing factories, reduction of employment opportunities in the fishing and fish trade industries. So many students dropped out of schools due to lack of school fees.

Table 1. Minimum Water activity for microbial growth

Micro-organism	**Minimum a_w for growth**
Clostridium botulinum	0.970
Salmonella sp.	0.950f
Vibrio parahaemolyticus	0.945
Staphylococcus aureus	0.860
Yeast	0.620
Molds	0.605

Adapted from Troller (1979).

Literature review

Fisheries play a significant role in rural African economy; earning livelihood for as much as 10% of the African rural population. The fisheries sector can play a significant role in creating new employment opportunities for Africa's rapidly expanding population. For every new job created in the primary fish production sector, another 3 to 5 jobs are consequently created in the post-harvest sector (Bernacsek, 1991). Smoking and frying of fish along the majority of the beaches no longer exist; in fact, some of the settlements in such beaches as Luanda K'otieno are now dying out (Ogunja, 1991). This is because filleting companies purchases most of the fish and the fish catches have also gone down.

Hot smoking.

This is carried out largely in mud-walled, often rectangular, smoking ovens. Weld-mesh is commonly used for the trays and shelves used to hold the fish in the kiln. Fish to be smoked are just gutted and washed and then cut into smaller pieces, and left in the open to drip-dry so as to prevent hardening during smoking. The smoke density and temperature are controlled crudely by opening or closing the shutter, and also by adding or reducing firewood. The smoking process takes about one to three days depending on the size, thickness and quantity of the fish.

As the smoking process continues, moisture is removed from the fish, until a level is reached where microbial spoilage, even at ambient temperature, will be prevented or will proceed slowly.

Pathogenic *Escherichia coli*

Six clinically distinct categories of disease causing *E. coli* have been described (Riley *et al,* 1983). Different virulence and infective characteristics are derived from a combination of the factors determining surface adsorption and adherence of the bacterial cells to the intestinal epithelium and the toxins that may or may not be produced.

Most of these organisms are not distinguishable from one another by simple biochemical or physiological tests. Since the time viro-toxigenic *E. coli* (VTEC) were first reported as human pathogens, several incidences of food-borne infections have been linked to it in many countries (Riley et al, 1983).

Salmonella sp.

Salmonella are Gram-negative facultative rods with peritrichous flagella. They are members of the enterobacteriaceae and are closely related to the genera *Escherichia* and *Shigella*. The genus *Salmonella* has only one species- *Salmonella enterica,* but more than 2000 serotypes exist, many of them pathogenic to humans and other animals.

Salmonella causes gastroenteritis and typhoid fever. The bacteria are more likely to multiply in food at warm temperatures. Typhoid fever is caused by serotype, *Salmonella typhi*. Lapses in sanitation can lead to outbreaks of salmonellosis. Drinking fecal contaminated water can also lead to an outbreak of the same. Fish harvested from contaminated waters can carry *Salmonella* sp. (FDA, 1984), (Pelzar *et al*, 1993).

Vibrio spp.

Vibrio is a genus of predominantly oxidase-positive, fermentative, motile gram- negative straight or curved rods. Thus a key characteristic differentiating them from the Enterobacteriaceae is their positive reaction to the oxidase test, although *V. metschnikovii* is oxidase negative. Many *Vibrio* spp. are pathogenic to humans and have been implicated in food-borne diseases. *Vibrio* spp. other than *Vibrio cholera* and *V.mimicus* do not grow in media that lack added sodium chloride, and are referred to as halophilic.

Pathogenic *V. cholera* produces a heat sensitive enterotoxin that causes the characteristic cholera symptoms, including rice water stool (FDA, 1992). *V. Cholerae,* the causative organism of cholera, is found in small numbers in freshwater environments. However, disease outbreaks are caused predominantly by contamination of water by faeces from infected persons, which lead to an increase in bacterial concentration in the water to above the minimum infective dose.

V. Parahaemoliticus is a halophilic bacterium found naturally in estuarine waters and animals. It has a world- wide distribution in estuarine and coastal environments and has been isolated from many species of fish, shellfish, and crustaceans. *V. Vulnificus* is a halophilic bacterium found in the estuarine environment and is similar phenotipically to *V. parahaemoliticus.* It causes food-borne and wound disease, either of which may progress to rapidly fatal septicaemia, especially in individuals with liver disease (cirrhosis) or other underlying illnesses such as diabetes (Blake *et al*, 1980).

Other halophilic *Vibrio* spp., including *V. fluvialis, V. hollisae, V. alginoliticus, V. furnissii,* and *V. metschnikovii,* have been associated with gastroenteritis and are present in estuarine environments with other pathogenic and non pathogenic species of *Vibrio cincinematiensis, V. damsela and V. carchanae*. *V. anguilae, V. damsela* and *V. carchanae* are pathogenic to fish (Pelzar *et al*, 1993).

Problem statement and justification

Fish is the main source of protein for the people living around Lake Victoria and given the prevalence of water and food-borne diseases in the riparian districts of the lake, it is in order that all possible infection routes of the pathogens be investigated and possible mitigation measures outlined. It is with this in mind that the research proposal was developed. Fish also forms a major source of employment. It’s transportation from the landing beaches to the markets is done using baskets, manila sacks and to a lesser extent tin-cans. Most of the landing beaches lack electricity and this makes it impossible for the fish dealers to have cold storage facilities. In addition, roads serving these areas are very poor and inaccessible during rainy seasons. These have led to a scenario where the fish that is not sold fresh to the processing industries or individuals, being processed in some way. Processing is done in the form of smoking, sun-drying or frying. The treatments employed in the processing are mostly inadequate resulting in the spoilage of the processed products.

The belief most people have is that smoked fish is sterile and can be eaten without further heat processing. In fact some people even eat the fish at the market before any post-smoking processing is done. The study was aimed at understanding the safety of smoked fish products during and after the smoking process. It identified microorganisms that contaminate smoked fish and made appropriate recommendations for mitigation. The findings of the study should be used to design steps necessary in lengthening shelf-life of smoked fish products and ways of avoiding smoked fish contamination with microorganisms.

Main objective
To examine the microbiological load of the smoked fish.

Specific objectives
1. To determine the number of *E. coli* counts in smoked fish.
2. To detect and quantify Salmonella species in smoked fish.
3. To enumerate Vibrio spp. in smoked fish.

Materials and methods

Study Area:
The major portion of Kenyan waters of Lake Victoria is a narrow gulf, known to various authors by several names: the Victoria Nyanza, Kavirondo Gulf, Nyanza gulf and the Winam gulf. All these refer to one and the same place. The Winam gulf has an area of approximately 1920 km with a length of about 60 km and width varying between 6 and 30 km (Rabuor and Manyala, 1991).

The Gulf lies within the equatorial region. The water temperature and solar radiation are relatively constant throughout the year (mean values are 22° ± 3°c and 1200 ± 140 E-’ S-’ respectively) (Rabuor and Manyala, 1991).

Sample collection.
Smoked fish samples were obtained from Awana, Mainuga, Balarawi beaches and Oyugis market in Rachuonyo District. Asat and Kaloka beaches and Kibuye market in Kisumu District and lastly from Homa-Bay Pier wholesale market in Homa Bay District. Tilapiine fishes and *Lates niloticus* samples, which were freshly smoked and others that had taken varied durations were bought from beaches and markets. Sampling was done using sterile plastic sample bags from the month of August 1999 to March 2000. They were labeled, kept in cooler boxes, indicating their beaches of origin and their history. Microbiological analysis was done on all the samples at the Kenya Marine and Fisheries Research Institute Laboratories (Kisumu) within 24 hours. The following parameters were analyzed viz: *Vibrio, Salmonella,* and *Escherichia coli.* A total of 45 tilapiine fishes and 44 *Lates niloticus* were analysed.

Laboratory Procedures

Microbiological analysis of fish

Enumeration of *Escherichia coli* biotype 1
E. coli biotype 1 was enumerated by the APHA (1992) method. 25g of test sample was homogenised in 225 ml. Serial dilution of 1/10, 1/100/ and 1/1000 were prepared as follows:

Step 1. Homogenized sample 1 ml + 9 ml blank (1:10)
Step 2. Homogenized sample 1 ml + 9 ml blank (1:100)
Step 3. Homogenized sample 1 ml + 9 ml blank (1: 1000)

Using forceps, sterile cellulose acetate membranes were transferred to the surface of dried nutrient agar. The membranes were gently flattened on the surface to minimize air pocket. Duplicate 0.5 and 1ml aliquots of the last dilution were transferred to cellulose acetate membranes. The fluid was spread over entire membrane except periphery, using a sterile glass spreader.

The plates were incubated for 4 hr at 35°C to facilitate resuscitation. Each membrane was then transferred to tryptone bile agar (TBA,Oxoid) plate and incubated for 18 hr at 44.5 ± 0.2°C. 2 ml of Vracko-Sherris Indole reagent were pippeted into each lid of the plates. Membranes were then removed from the agar and immersed in reagent for 5 min. After drying the membranes in sunlight for 20 min, pink stained colonies were counted within 30 min.

Isolation of Salmonella species

For isolation and confirmation of *Salmonella* sp., procedures recommended by FDA (1984) were followed. Analytical samples of 25g were aseptically weighed in duplicate. One portion was homogenized in 225 ml of selenite cystine broth in one blender jar. The other portion was also homogenized in tetrathionate broth base without brilliant green dye. The blending continued for 2 min. The blended samples were transferred to 500 ml Erlenmeyer flasks and left to stand for 60 min at room temperature with the jar securely capped. The pH was adjusted to 6.8 ± 0.2. 2.25 ml of 0.1% brilliant green dye was added to sample enriched in tetrathionate broth and swirled thoroughly. The jar caps were loosened 1/4 turn and the samples incubated for 18 - 24 hrs at 37^0C. Lids of the incubated samples were tightened and the samples shaken gently. Transfers of 1ml mixture to 10ml selenite cystine broth and another 1ml of mixture to10 ml tetrathionate broth were made. These were then incubated for 18 - 24 hrs at 37^0C.

The products that were directly enriched in selective broths were streaked on selective agars of bismuth sulfite agar (BSA) (Difco) and xylose lysine desoxycholate (XLD) agar (Oxoid), and Hektoen enteric agar (HEA) by applying 3mm loopful of incubated selenite cystine broth on each. The same was also done with tetrathionate broth. The BSA plates were prepared the day before streaking and kept in the dark. The plates were incubated at 37^0C for 18 - 24 hrs. Suspect *Salmonella* colonies were picked and inoculated into triple-sugar iron agar (TSI) (oxoid) and Lysine-iron agar (LIA) (oxoid). For identification, suspect colonies were confirmed by serological tests using polyvalent anti-sera (Fisher Diagnostics).

Detection and Isolation of pathogenic Vibrio species

Detection and isolation of pathogenic Vibrio species was done according to FDA method (1992). Samples of 25g were homogenized with 225ml sterile alkaline peptone water. Homogenates were transferred to sterile 500ml Erlenmeyer flasks and incubated at 37°C for 6h. A loopful was then inoculated on Thiosulphate-citrate-bile-salts-sucrose (TCBS) agar (Oxoid) and incubated for 18 - 24hrs at 37°C. 3 suspect colonies were picked from each plate, streaked for isolation on tryptic soy agar (2% total NaCl concentration), and incubated for 12hrs at 37°C.

Results

E. coli counts for beaches and markets.

E. coli were absent in the fish sampled from Awana, Asat and Kaloka beaches but Mainuga and Balarawi beaches had 3.2× 10^4 cfu/g and 2.1× 10^5 cfu/g respectively (Table 2). Tilapiine fishes from Kibuye had no *E. coli* counts. The Nile perch fish from the same market however, had 1.87× 10^4 cfu/g of the organism. Tilapiine and Nile perch fishes from Oyugis market had 1.5× 10^4 cfu/g and 1.3 × 10^4 cfu/g of *E. coli* respectively. The fish from Homa-Bay pier market had no colonies of the micro-organism.

Salmonella sp. counts for beaches and markets.

Salmonella sp. were absent from all the samples taken from both markets and beaches (Tables 2).

Table2: Average counts of colony forming units per gram (cfu/g) of fish samples from different beaches and markets

Beach/Market	*E. coli*	**Salmo**	**Vibrio**
Mainuga	3.2 ×10^4	0	3.2 ×10^3
Balarawi	2.1× 10^5	0	0
Awana	0	0	0
Asat	0	0	0
Kaloka	0	0	5.7×10^3
Kibuye (T)	0	0	0
(N/P)	1.9 × 10^4	0	0
Oyugis	1.5× 10^4	0	0
T) N/P)			
	1.3× 10^4	0	0
H-Bay **(T)**			
	0	0	2.5× 10^5

Vibrio spp. counts for beaches and markets

The V*ibrio* spp. were absent from fish caught from beaches except for Kaloka and Mainuga beaches which had 3.2× 10^3 cfu/g and5.7× 10^3 cfu/g respectively. Likewise, Kibuye and Oyugis markets were devoid of V*ibrio* spp. However, Homa-Bay Pier market had 2.5× 10^5 cfu/g. (Table 2).

Observations and Interviews

A garbage heap was observed within the market just where the fish is also displayed for sale in Oyugis market (Plate 2). At Homa-Bay Pier market, fish was displayed on manila sacks on the ground, which was littered with sugar-cane bargass and other forms of garbage. It was not uncommon to see the fish traders helping themselves, just less than 20 meters away from the market, hidden under some thickets.

Discussion

Although Nyagambi (1991), in his study showed that artisanal women fish processors and traders purchase fresh fish of good quality to ensure better end products, this study shows that smoking is usually done to the fish that were meant to be sold fresh, but due to saturation of the market with the commodity, could not be sold; or alternatively, fish that is rejected by large commercial filleting plants because it has started spoiling or is under-size. Instead of discarding this kind of fish, the fish is smoked and then transported to the markets to be sold. This situation is unlike Canada, (Dillion *et al*, 1994) where the fish processors choose fish of high quality.

It is envisaged in this study that fish processors be advised to choose high quality fish products. This is because, people eat smoked fish due to the flavour and texture that the fish acquires on smoking and they deserve to eat products of high quality. Choice of good quality raw material will also ensure longer shelf life of the products.

Awana beach smokes their fish in a similar way to the way it is done in Lake Turkana region (Ogunja, 1991), where the fish is smoked over simmering fire for two to three days. This ensures better end products. Such products have a more enhanced flavour, longer shelf life and appearance that is pleasing to the eye. However, the other beaches of Asat, Balarawi and Mainuga smoke their fish for less than a day and over flaming fire. This form of smoking does not produce fish products with the desired qualities. The processors rely on the hope that such fish are sold off to consumers the same day the fish are removed from the kilns, otherwise, such fish get spoilt and they would loose their money.

Post-processing handling of smoked fish products is not properly done. The smoked fish were observed to be put on dirty mats on the floor at Mainuga and Balarawi beaches. These are stores that are poorly ventilated and are generally dirty. There are no cold stores at the beaches and the fish are left in the ambient temperatures prevailing at the beaches. These temperatures go up to 37ºC. The fish are put in the stores where houseflies contaminate them very much with dirt from the surrounding environment.

Salmonella sp. was absent from all the samples analysed from the beaches Likewise Vibrio spp. was absent from those beaches except Mainuga beach (Table 1 and 3). This is in line with the requirements of Kenya bureau of standards (KBS) and EEC, (1991) regulations, which require that the pathogen should be absent from food. This is an indication that the smoking process kills the pathogens. It further implies good manufacturing practices being employed at the beaches.

It was observed in Homa-Bay pier market that the fish were just displayed on dirty manila sacks on the ground. This exposes fish products to contamination. Within the same market area were heaps of garbage and litters all over (pers. comm..).There were no toilet facilities anywhere in the vicinity of this open market at the shore of the Lake. The fish dealers and other people were seen attending to calls of nature within 50 meters from the market area. The condition observed in Homa-Bay applies to other fish market centers such as Oyugis and very many others along the lake region. Even the beaches that were sampled were in a serious wanting state for sanitary facilities.

Faeces and untreated water are the most likely modes for the contamination of foods. Human beings are believed to be the carriers of toxigenic and invasive strains of E. coli isolated from foods (Nieto and Magno-Orejana, 1984). This study concurs with the above observations and concludes that this is the major reason why disease outbreaks related to poor sanitary conditions are common along the beaches.

Fish are transported in non-insulated open trucks, where both the fish and the traders occupy the back of the open trucks. This post-harvest infection of smoked fish is in line with what Dillon *et al* (1994), studying microbiology of smoked fish in Canada found out , that the level of micro-organisms in fish reduces with smoking but increases with storage period and during transportation. It is therefore imperative that the necessary measures to arrest this situation be put in place if the smoked fish products have to remain wholesome and hygienic.

The people trading in the fish should be medically examined on a routine basis and be certified to be healthy before they can be allowed to handle the fish. This is not properly done usually. The markets should have raised racks for display of the fish. They should also be clean, have portable water and good V.I.P. latrines. These would go along way in averting the frequent disease outbreaks that have characterized these areas over the years.

Fish from the processing villages do not reach the outlet markets in time, as most of the feeder roads to these areas are poor and are impassable during the rainy season. This observation corroborates what Poulter *et al* (1988), found out in Zambia. Their study decried the pathetic state of roads to the villages. This study also underscores the need to make these roads all-weather roads to facilitate easy access to the markets.

Some of these smoked fish products are done poorly that if they don't reach the markets the same day, then they would be spoilt. This means loss of revenue to the fish processors.

TABLE 3: Anova comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from Mainuga, Balarawi, Awana and Asat beaches

PARAMETER	NUMBER n	MEAN ± SD	F 0.05; 6, 6,9, 9	P
LN *E. coli*	7 m 7 b 10 aw 10 as	6.345 ± 5.965 1.374 ± 3.634 0.000± 0.000 0.000± 0.000	7.15	0.001
LN *Vibrio spp.*	7 m 7 b 10 aw 10 as	2.316±4.104 0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00	2.95	0.048
LN *Salmonella sp.*	7 m 7 b 10 aw 10 as	0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00	0.00	0.00

m⇒Mainuga b⇒Balarawi aw⇒Awana as⇒Asat
n⇒Number of samples analyzed

TABLE 4: ANOVA comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from Kibuye and Oyugis markets

Parameter	Number n	Mean ± SD	F 0.05,3, 5	P
LN *E. coli*	4 k 6 o	2.806 ± 5.613 3.450 ± 5.364	0.03	0.860
LN *Vibrio spp.*	4 k 6 o	0.00 ± 0.00 0.00 ± 0.00	0.00	0.00
LN *Salmonella sp.*	4 k 6 o	0.00 ± 0.00 0.00 ± 0.00	0.00	0.00

k⇒Kibuye market o⇒Oyugis market n⇒Number of samples analyzed

It was encouraging to note that no colonies of *Salmonella* sp. were observed for all the three markets of Kibuye, Oyugis and Homa Bay Pier (Table 5). Presence of one single colony of *Salmonella* sp. in the fish exported to the European union market would cause the whole consignment to be rejected. Previously, there have been bans of fish products from Kenya due to such reasons. These bans affect the economies of the people and should be avoided by following the good processing practices.

Rogers and Mosille (1991), in their study of Nile perch smoking in Tanzania, wrote that the smoking process in the kilns is essentially similar. Air temperatures of 120ºC-140ºC are generated in the kiln, with the temperature of the fish rising to around 100ºC. With this kind of temperatures, the smoked fish are expected to be sterile immediately after smoking. As Rogers and Mosille (1991) reported, the temperatures in the kiln is such that the fish is initially cooked, denaturing the enzymes and protein, killing most bacteria and halting spoilage.

Since even one colony of Vero-toxigenic *E. coli* is enough to cause a disease (ICMSF, 1978), proper hygiene procedure must be put in place to curb possible disease outbreaks as a result of food, from these markets, being contaminated with the pathogens as all the markets had a lot of *E. coli.*

Infrequent outbreaks, which often involve *Clostridium botulinum* toxin, consistently appear related to improper processing procedures applied by inexperienced or un-knowledgeable processors, inadequate sanitation, abuse of product storage conditions (primarily by the consumer), and sometimes to consumer's erroneous belief that smoking negates the need for refrigeration or that the product has unlimited shelf-life.

TABLE 5: Anova comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from markets versus beaches

Parameter	**Number Y**	**Mean ± Sd**	**F 0.05; 9, 33**	**P**
LN *E. coli*	10 Z 34 X	3.192± 5.157 1.589±3.900	1.13	0.295
LN *Vibrio spp.*	10 Z 34 X	0.00 ± 0.00 0.477± 1.991	0.56	0.457
LN *Salmonella sp.*	10 Z 34 X	0.000 ± 0.000 0.000±0.000	0.00	0.00

Z⇒Markets X⇒Beaches Y⇒Number of samples analyzed

Form the ANOVA results it is clear that markets have higher loads of bacteria that were analyzed for compared to the beaches (Table 2 and 6). This indicates cross contamination of the fish products by the traders at the markets or poor sanitary conditions during storage and distribution. The fish handlers at the beaches and markets should be taught about good food handling practices. Those with wounds should not be allowed to handle fish (Dillon *et al,* 1994).

There were nil *Salmonella* sp. cfu counts for both the markets and the beaches. This is an indication of proper handling procedures in both the markets and the beaches as far as the pathogen is concerned.

The standard deviation for the markets was also high indicating that the fish from different sources undergo different processing standards. It also indicates differences in hygienic conditions observed in different markets.

Even though smoking used to be a major fish processing technique earlier on, it is no longer the same now. Other more preferred processing methods such as filleting has taken up its place, deep-frying and sun drying. This observation can partly be explained by the scarcity of wood fuel. Smoking process requires a lot of selected wood fuel. This is unlike deep-frying that does not discriminate on the type of wood used. More so, deep-frying requires less wood. It also uses other materials such as offal. The kilns that are in use in this area are not economical, as they do not conserve fuel.

To keep losses to a minimum, the cured fish should be distributed and sold as soon as possible. In remote areas, however, this is not always possible since transport may only be available periodically. Furthermore, it is often necessary to accumulate sufficient fish to fill a truck completely, for small- scale producers, this can take many weeks. Also, where communication is poor, regular transport often breaks down and hence cannot be relied upon. In addition, roads are often in poor condition, regularly impassable for part of the year due to floods etc. Under these conditions, storage losses can be very high (Morrisey, 1988).

Conclusion

In order to lengthen the shelf life of smoked fish products, it is necessary for the smoking process to be longer as is done in Uganda (Achieng pers. Comm.), and to reduce the moisture content to less than 50% below which the bacteria will not thrive.

Though a lot have been done in creating awareness among the fish traders and processors on the need to conduct their operations under good sanitary conditions. In spite of the above achievements, much still need to be done especially among the markets where the bacterial loads were still very high. Homa-Bay pier market in particular, needs serious sanitation improvements, ranging from the way the fish is displayed for sales to provision and enforcement of proper use of toiletry facilities.

The measures that have been taken by the various institutions in ensuring production of high quality fish products should be maintained in order for us to continue exporting our fish products to the European market.

Recommendation

A slow simmering fire for about three days should be used during the smoking process. This will result in properly smoked fish products with low water activity. Such products take up to more than a month to spoil thereby allowing ample time for marketing.

Post-processing handling of smoked fish products should be improved. The fish should be stored in clean, well-ventilated stores in the absence of cold storage facilities. The fish products should be packed in well-ventilated baskets and be transported in properly- sanitized trucks.

Smoked fish products must be properly cooked before they can be eaten.

For extended storage life, smoked fish products should be frozen to protect quality except for hard-cured items. Adequate toilet facilities and good sanitary conditions should be put in place in all the smoking villages and markets. Raised racks for fish displayed for sale in the markets are recommended. Good management practices at the fish processing plants and improved health status of the local population would ensure continuous acceptability of fish products from Kenya.

Further research should be done with the aim of innovating smoking-kilns that conserve fuel-wood. Re-forestation programmes to be instituted in the areas surrounding the smoking villages. Road network along the landing beaches and fish processing villages should be improved so as to make them all-weather roads. This would facilitate delivery of the fish products to the markets in time.

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Community participation in fisheries management: prospects and challenges for co-management

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Abstract

Fisheries play an important role in the economy of Uganda, contributing to foreign exchange, food security and employment. In 1998, the total fish catch landed was 217,100 metric tons of which Lake Victoria contributed 48.6%. The development of government centred management systems has led to increasing alienation of resource users and to wilful disregard of specific regulations. The realisation of the problems faced by the current management systems has led to the recognition that user groups need to be actively involved in fisheries management if the systems are to be consistent with sustainable fisheries and be legitimate. Community participation in fisheries management (Co-management) is being tried in Lake Victoria, through co-management, which is the sharing of responsibility between the government, researchers and the resource users. A study on co-management was carried in the fisher communities on Lake Victoria, Uganda in July 1999 and between October – November 2000, to assess the potential for implementing a community-based co-management approach on the fishery. Results of this study show that there is a general agreement between the staff and fisher-folk on the need to share management responsibilities. Fishers generally agreed that giving more responsibility for fisheries management to local fishermen will yield positive results in terms of control of fisheries malpractices, willingness to collect and give accurate data and compliance with regulations.

Keywords: Community participation, co-management, fisheries resources management

Introduction

The management of the fishery resources in Uganda has been the role of government vested in the Fisheries Resources Department with no input from the fisher folk. The Department is responsible for policy formulation, review of laws and regulations, fisheries extension services, monitoring, law enforcement and control. The staffs at the landings carry out extension, collect data and enforce the regulations. The rules and regulations are contained in the Fish Act 1964. Despite the Act being in operation since 1964, the fish catches and biodiversity have continued to decline. Consequently there is a growing feeling that the fisheries has been grossly mismanaged with fishermen having no respect for management laws and regulations.

It has been realized in a number of fora that there is great need to involve fisherfolk and other stakeholders in the management of the fisheries (CIFA, 1989; MAAIF,1997; UFFCA, 1998). However, there is general lack of information on the capacity, commitment and willingness of the fisherfolk to participate effectively in fisheries management and development activities. This study was undertaken in July 1999 and then followed up in October – November 2002 to study the participation of communities since the implementation of co-management under LVEMP started.

Materials and methods

Materials for this paper includes both primary data obtained through field study, secondary information collected from a number of documents both published and unpublished but documented proceedings from various community participation workshops. Literature review on co-management was carried out.

The primary data was collected covered both mainland and island landings on Lake Victoria. Rapid Rural Appraisal tools (RRA) were used. A structured questionnaire was administered to some fisher folk selected randomly in the landings visited. The large landings with settlements along the lakeshores were listed and those to be visited were randomly picked from the list

Field staffs were used as interpreters where there was language barrier and the purpose of the research was explained to both the staff and the respondents. Where the educational standard was low and to save on time for individuals filling the forms, focus group discussions were held following the same structured questionnaires for comparison purposes. A similar questionnaire was given to staff both at the headquarters and in the field. Information collected included:

- Involvement in the fishing industry
- Knowledge of the fishing industry
- Preferred future management options and management structure
- Factors which have contributed to the problems of lake Victoria fishing Industry
- Their opinion of what impact may occur if more responsibility for managing the fisheries was given to the local fishermen.
- Membership of fishermen's organizations

Results

Involvement in the fishing industry

A total of 153 individual fisher folk respondents, 70 fishers for Focus Group Discussions (FGD) and 15 staff. The results revealed that the fisheries industry on Lake Victoria is dominated by youth most of them below 35 years of age. Table 1(a) shows age groups for fishers while Table 1(b) shows time spent in the fishery. Most fishermen live in fishing villages without adequate social facilities such as schools and health facilities. A majority of the fishermen agree that the educational standard of most fishermen is very low (Table 1(c)).

Table 1a. Employment in the fishing industry (%)

AGE GROUP					
	<20	20-29	30-45	46-60	>60
Boat Owner	1.1	29.8	58.5	10.6	0
Boat Crew	13.3	26.7	60	0	0
Others	0	42.9	57.1	0	0
TOTALS	4.6	30.1	58.8	6.5	0

Table 1b. Time spent in the fishing industry (%)

	AGE GROUP				
TIME	<20	20-29	30-45	46-60	>60
Full-time	2.6	24.2	41.8	5.2	0
Part-Time	1.3	5.2	17.6	1.3	0

Table 1c. Rating of general fishers' educational standards (%)

CATEGORY	EDUCATIONAL STANDARDS		
	Good	Average	Poor
Boat Owners	4.76	42.86	52.38
Boat Crew	4.54	40.91	54.55
Others	0	41.67	58.33

Knowledge of the fishing industry

Fishing pressure

Most fishers perceive a decline in overall catches (Table 2a). Among the fishers and fish dealers, 92.9% from FGD said the fishery is worse while 61.8% from individual respondents agreed and 93.3% of the staff shared the same view. All the three categories agreed that the major contributing factors were use of wrong fishing gears and methods, and too many boats/too much fishing (Table 2b). Some fishermen have as many as 30 boats and on some fish landings people have as many as 100 nets per boat.

Table 2a. Current state of the fishery (%)

	As Good	Better	Worse	Not Sure
Individuals	12.5	24.3	61.8	1.4
FGD	0	7.1	92.9	0
Staff	6.7	0	93.3	0

Table 2b. Reasons for current state (%)

	Individuals	Focus Group	Staff
Too much fishing	31.5	48.6	60
Too little investment	44.9	5.7	0
Too many boats	30.9	57.1	33.3
Disappearance of some species	41.9	21.4	53.3
Use of harmful gears	52.8	64.3	80.
Others	0	60.0	0

Percentages are calculated from total number of respondents.

Those who said the catches were good think there was still plenty of fish in Lake Victoria and changes in quantity caught were seasonal and related to the weather conditions. Some fishers observed that they had been fishing for many years with good catch yields. Others believed the total catch could still be the same except it is being divided amongst too many boats. However, even those who said the fishery was better conceded that there was too much fishing and too many boats.

Use of harmful gears was the most cited reason for the poor state of the fishery. There was a complaint of destructive gear such as beach seines, use of poison and the new habit of tying 2-3 nets together to achieve greater effective fishing depth, which does not allow fish a chance to escape. There is also use of nets of less than 4" mesh size and some of these are made locally at the landings. Other reasons included infestation by the water hyacinth and lack of proper monitoring by fisheries managers.

Preferred management options and structures

Following the use of destructive gear that included fish poisoning and the subsequent ban on fish export to the European market, many fishermen suffered since most of them did not have alternative employment. Most fishermen agreed that it was difficult for those already engaged in fishing industry to earn a living by doing anything else since they didn't have the knowledge of saving and therefore did not have capital to start other businesses. Most fishing crew spend most of their time in the lake and have no other skills to join alternative jobs. They believe that fishing is the only form of employment available to them and hence are opposed to the idea of restricting entry to the fishery believing everybody needs a chance to earn a living. Another strong belief was that any Ugandan is free to fish in Lake Victoria. This also supports the idea that many fishermen acknowledge there are too many boats and nets on the lake contributing to the decline in catches per net.

There is also indication of crowding in the fishing grounds as everybody tries to go to those areas with good catch. From the responses given, 21.2% said the crowding was a lot, 61.8% said there was some but not much while 17% said there was none.

Table 3 shows that fishermen are inclined to regard positively the management measures that are already in place. The current management measures in use include gear regulations and minimum size of Tilapia and Nile perch allowed to be landed. Gear regulations were found favorable and they felt that the minimum mesh size should be increased to 6 inch. Others wanted beach seines to be allowed but their mesh size to be regulated. Limitation of vessels and gears was favored by individuals especially those who were educated and understood the impact of too much fishing pressure. However, they suggested that limitation should be on number of boats and nets allowed per person. Closed area was rated high among the FGD. Focus group participants had a chance to learn from older fishermen the existence of closed fishing areas in Tanzania where it is being used as one of the management measures. Also those who emigrated from Lake Albert recalled that the closed areas existed and were good for conservation purposes. Fishers opposed closed seasons arguing that there was no improvement in fish catches when the lake re-opened following the ban on fishing during the fish poison problem.

Table 3. Preferred future management options (%)

	Closed Area	**Closed Seasons**	**Gear Regulations**	**Limited Vessels/gear**	**Others**
Individuals	10.2	3.9	64.8	20.3	0.8
FGD	65.7	0	34.3	0	0
Staff	20	6.6	26.7	46.7	0

As far as management structures are concerned, results from Focus Group Discussion indicate that 85% preferred a management structure of equal partnership between

Government and the fisher folk organizations. Responses from individuals indicate 42.7% want fishermen's organizations to take over management and be advised by Government while 35.9% preferred equal partnership (Table 4). Results from FGD are more indicative because participants had a chance to discuss disadvantages and advantages of each option. However, those groups, which opted to have government continue with the responsibility of management, reasoned that most of the current Landing Management Committee members are corrupt and it was difficult to trust fishermen to police themselves. Some agents for the factories interviewed preferred to have the fishermen's organizations take over management arguing that government officials have failed and field staffs are vulnerable to corruption.

Table 4. Preferred Future Management Structure (%)

	Government	Fishermen's Organizations	Partnership
Individuals	21.4	42.7	35.9
FGD	14.3	0.0	85.7
Staff	60.0	13.3	26.7

On the other hand, 60% of the staff interviewed preferred to continue with Government as managers but this time advised by fishermen's organizations, while 26% preferred equal partnership. This shows that Staff still don't trust the fisherfolk to be capable of taking on management responsibilities.

Responsibility for future management

The idea of co-management was welcomed by a majority of people. There is a general feeling among fishermen that there is need for them to participate in management issues. They reasoned that fishermen know each other and since they live with each other, they are in a better position to carry out some of the duties like law enforcement and monitoring. Some fishers even think they know better how much fish is in the lake and can advise better on stocks and allowable catch than fisheries managers who sit in the office. Their argument is that they spend most of their time on the water, they know fish movements and good fishing grounds. Table 5 gives their views on who should be responsible for what activity.

Table 5. Preferred Responsibility for Future Management (%)

5a. Individual Responses

	Fish. Dept.	FIRRI	District	Fishers Org.
Stock Assessment	31.2	38.9	0.8	28.1
Determining Total Allowable Catch	35.3	28.6	2.5	33.6
Determining Management Measures	52.0	10.6	5.7	31.7
Enforcement of Regulations	29.6	3.2	18.4	48.8
Licensing Fishing Activity	50.8	0.8	30.0	16.4
Monitoring and control	42.4	12.8	11.2	33.6
Quality Assurance	61.6	25.6	0.0	12.8
Fish Price Control	12.8	4.3	2.6	83.3

5b. Focus group discussion

	Fish. Dept.	FIRRI	District	Fishers Org.
Stock Assessment	0.0	100	0.0	0.0
Determining Total Allowable Catch	35.7	28.6	7.1	28.6
Determining Management Measures	35.7	0.0	7.1	57.2
Enforcement of Regulations	30.0	0.0	0.0	70.0
Licensing Fishing Activity	42.8	0.0	28.6	28.6
Monitoring and control	64.3	5.7	0.0	30.0
Quality Assurance	42.9	5.7	0.0	51.4
Fish Price Control	37.1	0.0	5.7	35.7

5c. Staff

	Fish. Dept.	FIRRI	District	Fishers org.
Stock Assessment	25.0	75.0	0	0
Determining Total Allowable Catch	23.5	64.7	0	11.8
Determining Management Measures	56.3	37.5	6.2	0
Enforcement of Regulations	52.9	0	29.4	17.7
Licensing Fishing Activity	64.7	0	29.4	5.9
Monitoring and Control	77.8	0	11.1	11.1
Quality Assurance	81.3	0	6.2	12.5
Fish Price Control	7.1	0	14.3	78.6

From the results, there is a general preference among both the individual respondents and FGDs for fishermen's organizations to take over the responsibility of enforcement while the Fisheries Department should remain responsible for monitoring, control and quality assurance. Licensing is an activity that could be jointly done by the Fisheries Department, the District Administration and the fishermen's Organization. Determination of total allowable catch could be jointly done by the Fisheries Department, Fisheries Research and the Fishermen's Organization while stock assessment can be done by Researchers in collaboration with the Fishermen's organizations.

There was a general feeling among fishers that giving more responsibility for fisheries management to local fishermen will yield positive results in terms of control of law breakers, reducing the level of immature fish catches, willingness to give accurate data, compliance with regulations and solving problems among fishermen. Tables 6.1, 6.2 and 6.3 present the results from the three groups.

Table 6. Effect of giving more responsibility to local fishermen (%)

6a. Individuals

	Good	Bad	None	Not Sure
The Control of Law Breakers	65.2	26.5	5.3	3.0
The Level of Immature Fish Catches	56.2	37.7	3.8	2.3
Willingness to give accurate data	52.7	24.0	7.8	15.5
Compliance with regulations	68.2	20.9	3.9	7.0
Solving problems among fishermen	80.6	9.3	5.4	4.7

6b. Focus Group Discussion

	Good	Bad	None	Not Sure
The Control of Law Breakers	78.6	21.4	0	0
The Level of Immature Fish Catches	92.9	7.1	0	0
Willingness to give accurate data	78.6	21.4	0	0
Compliance with regulations	71.4	7.1	0	21.4
Solving problems among fishermen	100.0	0	0	0

6c. Staff

	Good	Bad	None	Not Sure
The Control of Law Breakers	53.3	13.3	26.7	6.7
The Level of Immature Fish Catches	33.3	40.0	20.0	6.7
Willingness to give accurate data	26.7	40.0	20.0	13.3
Compliance with regulations	33.3	26.7	33.3	6.7
Solving problems among fishermen	80.0	6.7	6.7	6.7

Fishermen were very positive on achieving better management success since they know each other and fishermen will respect laws that are implemented by fellow fishermen. However, some were very skeptical arguing that their leaders will equally be corrupted and since those elected to leadership are the more influential persons and also often the wrong doers, giving responsibility to fishermen will yield bad results. They prefer leaving the responsibility with the Fisheries Department. Many wondered how they would be able to coordinate what goes on in other parts of the lake. Leadership is a problem and in the past cooperative attempts failed due to lack of proper leadership, embezzlement, lack of proper mobilization and lack of support from the government. Therefore, a lot of effort is needed if co-management is to work. Government should mount sensitization to teach fishermen new regulations, and fisheries conservation.

Factors contributing to the problems of Lake Victoria fishery

From the responses, there is some indication of the factors contributing to the problems of Lake Victoria, although respondents seemed to differ and most of them indicated more than one option (Table 7). The major contributing factors was insufficient penalties cited at 31.8% by the fishers. From the results in Table 7, the Crew and FGD rated lack of conservation highest problem.

Table 7. Perceptions on factors contributing to the problems of Lake Victoria Fishing Industry (%)

	Boat Owners	Crew	Others	FGD	Staff
Fishermen have no say in management	55.3	44.4	64.3	62.9	6.7
Fishermen’s knowledge not used to formulate management measures	60.6	48.9	35.7	48.6	6.7
Fisheries regulations don’t suit local conditions	47.9	48.9	20.0	27.1	13.3
Insufficient penalties	66.0	66.7	35.7	62.9	46.7
Fishermen not free to report law breakers	46.8	51.1	35.7	35.7	20
No sense of conservation	57.4	71.1	35.7	72.9	20
Other factors	36.2	13.3	0	64.3	0

Percentages are calculated from the total number of respondents.

Awareness of rules and regulations (Fish and Crocodiles Act 1964) is not high among the fisherfolk. Most of the fishers are youths below 35 years of age and most of them have been in the fishing industry for less than 10 years. They have not been exposed to the rules and regulation and more so the reason why those regulations were put in place. Some of them have come to know beach seines are not allowed because of the arrests made by staff. However, they don't know the impact the seines have on the fishery. Fisherfolk agreed that many fishers do not have sense of conservation and only think of "food for today". There was also a feeling that those using poison are not the genuine fishermen but people who want to make quick money.

Previously, fishermen were not free or did not care to report those who break laws because it created enmity among them but with the creation of Fish Landing Management Committees, the fishermen are now very free to report law breakers and the use of poison is vigilantly monitored by all fishermen. Major causes of the fishers behavior cited by fisher-folk included: Poverty, ignorance due to lack of sensitization, lack of information, and high illiteracy rate; lack of fishermen's organizations through which to voice their concerns; and nomadic life of fishermen.

Community based organizations

Majority of fisherfolk operate as individuals and there are very rudimentary forms of organizations or associations existing and these are not registered. Out of the 30 fish landings visited during the period October- November 2000, only 7 had organized groups. These groups were at varying stages of stability and none was registered in-spite of the fact that some had existed for as long as 10 years. Some of the groups were formed after their head fishermen or those members who attended some of the Socio-economics sub-component workshops went back and informed their communities that every landing was required to form a group and open up a bank account. Groups were hurriedly formed and accounts opened but no form of financial assistance has come from LVEMP and this has led to discouragement.

The communities in all the landings visited were non-homogeneous. Main problem why there are no viable groups is lack of sensitization on need for groups and how to run the groups. In some cases there was lack of leadership. Another problem is that fishermen lack trust amongst the community residents.

Findings from workshops

Workshops were conducted and attended by representatives from all the ten districts of Lake Victoria. In all these workshops there was general agreement on need for community participation in fisheries management bearing in mind that they interact with the resource daily and know those within their communities. However, some questions were raised:

a) How will government enforce its laws on fishermen who are now expected to mobilize their own financial resources to manage the lake?
b) How co-management shall overcome LC bureaucracy and use of firearms in fishing?
c) How shall co-management get powers to arrest and prosecute wrong doers?
d) How is monitoring of co-management to be done?

Main issues raised by workshop participants included the following:

- Few fisheries staff on the ground
- Inadequate coordination between fisherfolk and staff
- Illegal gears and methods
- Free entry to the fishery
- Roles and powers not well defined in the Act
- Lack of patrol boats
- Landing task force members are now abetting catch and sale of immature fish
- Presence of numerous security organs on the lake with difficulty in differentiating who is doing what
- Too many ungazetted fish landing sites which makes it difficult to monitor
- Migration of fishers making registration difficult and registration has no legal backing
- Effectiveness of landing management committees is limited
- Political interference in fishing gears
- Lack of harmonization of management measures across the districts
- In community participation there is option of "no action"

Discussion

Co-management

In its definition, fisheries co-management is the sharing of the management responsibility between government institutions and the resource users.

Currently, government is still the centre of fisheries management. The new approach now should be co-management, where the resource users together with government share the responsibility for managing the resource for sustainability. In co-management, local organizations clearly define and share specific management responsibility and authority. By working together with the government, all the tasks related to resource management could be addressed.

There is lack of written community rights on control and enforcement of instituted measures by the Beach Management Units (BMUs) under the current co-management arrangement being tried. There is also lack of co-ordination and harmonization of the control and management measures by the districts.

Fishermen are eager to participate as seen from the results of the fieldwork where 85% from FGD and 35.9% from individual responses preferred equal partnership while 42.7% of individual responses reflected the wish to have fishermen's organizations take over management with government acting in advisory capacity. The same interest has been echoed in a number of community participation workshops. What remains is to work out clear structure of how to share the responsibilities between government institutions and the resource users.

In co-management, fishermen's views are represented through fishermen's organizations or equivalent institutions. Fisherfolk need to organize themselves into groups and be willing to work collectively to get their voices heard.

Conditions for successful co-management

Community-based management in fisheries has been documented around the world over the last decade and the on-going research by a number of social scientists has revealed some conditions that appear to be central to the chances of developing and sustaining successful co-management agreements. Ostrom, (1990) and Pinkerton, (1989) have identified some emerging conditions for successful co-management and they believe that the more the number of these key conditions that exist in a particular situation or system, the greater the chance for successful co-management.

Some key conditions for successful co-management would include the following:

i) *Clearly defined boundaries*: The physical boundaries of the area to be managed should be distinct so that fisher groups can have accurate knowledge of them. The boundaries should be based on an ecosystem that allows for management with available technology, i.e. transportation and communications.

ii) *Membership is clearly defined:* The individual fishers or households with the rights to fish in the bounded fishing area and participate in area management should be clearly defined. The numbers of fishers or households should not be too large so as to restrict effective communication and decision making.

iii) *Group cohesion:* The fisher group or organization permanently resides near the area to be managed. There is a high degree of homogeneity, in terms of kinship, ethnicity, religion or fishing gear type, among the group. Local ideology, customs and belief systems create a willingness to deal with collective problems. There is a common understanding of the problem and of alternative strategies and outcomes.

iv) *Existing organizations*: The fishers have some prior experience with traditional community-based systems and with organization, where they are representative of all resource users and stakeholders interested in fisheries management.

v) *Benefits exceed costs:* Individuals have an expectation that the benefits to be derived from participation in and compliance with community based management will exceed the costs of investments in such activities.

vi) *Participation by those affected:* Most individuals affected by the management arrangements are included in the group that makes and can change the arrangements. The same people that collect information on the fisheries make decisions about management arrangements.

vii) *Management rules are enforced:* The management rules are simple. Monitoring and enforcement can be effected and shared by all fishers.

viii) *Legal rights to organize:* The fisher group or organization has the legal right to organize and make arrangements related to its needs. There is enabling legislation from the government defining and clarifying local responsibility and authority.

ix) *Cooperation and leadership at community level*: There is an incentive and willingness on the part of the fishers to actively participate, with time effort and money, in fisheries management. There is an individual or core group who takes leadership responsibility for the management process.

x) *Decentralization and delegation of authority*: The government has established formal policy and/or laws for decentralization of administrative functions and delegation of management responsibility and/or authority to local government and local group organization levels.

xi) *Coordination between government and community*: A coordinating body is established, external to the local group or organization and with representation from the fisher group or organization and government, to monitor the local management arrangement, resolve conflicts, and reinforce local rule enforcement.

The principles of community based co-management

Some of the basic principles of community Based Co-Management include the following:

i) The delegation of authority from governments to community co-management Committees.
ii) Representatives of the fishing industry in the local community are the primary participants on the community committees.
iii) Leaders of community groups and institutions are participants on the community committee.
iv) Committee members are accountable as a body to the local community.
v) The committee will make every effort to govern by consensus.
vi) Committee decisions will take into consideration the sustainability of the industry and the community, and will also address social, economic and ecological factors.
vii) Industry, community and government as decided by the government and the committee will share financial responsibilities and/or rewards for co-management.
viii) Committee members will participate in open and transparent communication.
ix) All available information in the industry will be available to all committee members.
x) Training and/or education will be made available to stakeholders as required for their full participation.

Community and institutional design

In implementing co-management, there will be a need to identify who is the community that is to participate. It is important to define the community, the focus and scale of the community and how the various groups within the affected community are represented. Co-management requires functional communities, with characteristics, which are conducive to co-operation.

Not every fisher-folk will be directly involved in decision-making and implementation. They will have to elect their representatives who will speak for them. There will be different categories that are directly affected by changes in the fishery, namely: the fishers, fish traders, artisanal processors, industrial fish processors, consumers and the environmentalists.

If co-management initiatives are to be successful, basic issues of government legislation and policy to establish supportive legal rights and authority frameworks must be addressed. The establishment of an appropriate government administrative structure and an enabling legal environment are essential in efforts to promote and sustain existing local-level fisheries management system and/or to develop new co-management system (Pomeroy and Berkes, 1997).

Challenges to implementation of co-management in Uganda

Socio-economic issues

Despite the advantages of co-management, there are some difficulties, which may impede the establishment of the system. "Population growth and technological change have increased pressures on natural resources to the extent that 'minimum' common property rules do not provide effective regulations. Local institutions, weakened by far-reaching economic and political changes, are unlikely to impose intensive controls, especially where there is little precedent for direct regulation. Local common property management will not emerge simply by giving greater official rein to local action". (Baland and Platteau, 1996:287). Effective local-level management is impossible without the existence of institutions and mechanisms suitable for achieving consensus among fishermen participating in the fishery.

Fishermen's organisations

There are very few fishermen organisations and most of the existing ones are not viable. Most fishermen do not have the experience of belonging to an organization and the record of the two main existing organizations (UFFCA and UCFU) is poor on the ground.

Fishermen join organizations with hope of quick gains in terms of free fishing inputs and other benefits. They want to receive but not to give. This is a stumbling block, which can only be removed with concerted effort in education and sensitization. Fishermen should be made to understand that these organizations are a voice for their contributions towards building a better fishery, which is acceptable to all users.

Sustainable funding

The introduction of community-based co-management undoubtedly requires extra financial resources. One of the principles of community based co-management is, it requires sufficient staff and financial resources to support the process. The central government, local government and community participants should make financial support for fisheries management activities and for the co-management teams, committees, etc., available. Even where Landing management committees have been put in place, they are starting to relax and most of them expect to be paid a government salary for community work they are doing. The perception that the resource is government's property and as such it is government's responsibility to protect it is still hanging over the people.

Legal provisions

The old Fish and Crocodile Act did not have provision for Community involvement in fisheries management activities. The Fisheries Resources Department under Lake Victoria Management Project has started the co-management approach. The fisherfolk from selected landings have been sensitized through workshops on co-management principles and Landing Management Task Forces have been launched in pilot landings in all the districts of Lake Victoria. There is need for commitment from all sections of government i.e. political, Central and Local governments.

Community based resource management is a new concept in the fisheries industry and it will take time for the fisherfolk to appreciate their full responsibility. The fisherfolk of Lake Victoria are very enthusiastic about participating but because of the rampant lake piracy armed people using illegal gears on the lake many fisherfolk don't have confidence yet. Influential people who are often lawbreakers get elected to landing management committees, eventually compromising the enforcement of regulations. Political considerations can seriously threaten the viability of co-management

Basic issues of government legislation and policy to establish supportive legal rights and authority frameworks must be addressed.

Open access policy

The current policy of "open access" is not conducive for co-management as it makes it difficult to enforce cooperation and agreed upon rules because of the "free-rider" problem. Also migration of fishermen makes collective community action difficult. Government will have to do away with the "open access" and shift to "common-property" resources held by the state with an identifiable group of users. Resources held by users in common can be withheld by other members through a group decision and can thus be employed as a sanction against users who break the rules

Recommendations

The following are suggested recommendations for future action:

- Concerted effort at sensitization targeting all levels of stakeholders from district to community on principles and advantages of co-management is needed.
- Basic training in fisheries management, book keeping and business skills should be provided to the fisherfolk if they are to be able to diversify their economic activities and pull out of perpetual poverty.
- Policy on "open access" needs to be reviewed
- Set up management structures with clearly defined roles

- Agree on funding mechanism with contribution from Central government, local government and communities to sustain co-management activities.
- Formation of fisherfolk organizations will have to be carried out as part of the process to develop co-management.
- Sufficient and reliable information is needed for successful co-management and it should be made available to all participants.
- Fish Act should be reviewed in consultation with fisherfolk communities if the laws are to be acceptable and enforceable.

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Factors Influencing Involvement of Local Communities in the Fishing Industry in Lake Victoria, Tanzania: From Production to Marketing

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Abstract

A large number of local communities surrounding Lake Victoria in Mara, Kagera and Mwanza regions in Tanzania earn their living from fishing industry. The industry is based on various types of fishes but Nile perch and sardines are the most predominant species. Through sample size of 432 respondents, selected randomly from those regions, factors influencing involvement of local communities in the fishing industry have been identified. The identifications are based on descriptive statistics and logistic regression models. The results on fishing production show that several factors influence positively involvement in fishing industry. Among them are ability to fish and significant ($p<0.10$), household size and significant ($p<0.05$). Those influencing negatively are also several. This includes number of dependants in the household and significant ($p<0.10$). Factors influencing involvement of fish processors are many. This includes household size and significant ($p<0.10$) while negatively is age of household head and significant ($p<0.10$). Similarly, factors influencing marketing are long list. Influencing positively is household size and significant ($p<0.01$). Negatively are number of dependants and age of household head and significant at 0.01 and 0.05 levels respectively. It is concluded that socio-economic factors such as abilities, sensitisation through education, transportation (distance from the beach to nearest town), gender and household size, district and tribe be considered in depth as they influence involvement of local communities in the fishing industry. Along side these factors, it is recommended to know the effect of involving local communities in the industry, especially on the management of the lake Victoria through using policy, regulations and laws.

Keywords: fish production, processing, marketing, ability, socio-economics

Introduction

Local communities around Lake Victoria in Mara, Kagera and Mwanza regions, Tanzania are involved in fish production, processing and marketing due to the fact that fish industry plays important role on their living. According to FAO (1989) cited by Bwathondi (2000), in between 1987 and 1989, about 37-39% of Tanzania's total consumption of animal protein was derived from Lake Victoria's (LV) fish. That was equivalent to 50% of total fish supply in Tanzania. Furthermore, fishing industry created employment to about 13,172, 5,192 and 1,700 fishermen/women in production in Mwanza, Mara and Kagera regions in 1994 respectively (URT, 1997, 1998a 1998b). In addition, reliable supply of fish enabled construction of several fish fillet processing industries in those regions. In 1997, Mwanza and Mara had 7 and 1 industries respectively.

Despite the important role of fishing industry, the returns are not sufficient. This is evidenced by poor livelihood experienced by communities relying on fish industry. For instance, fishermen live in grass-thatched houses, which are not hygienically recommended and malnutrition is still prevalent (Onyango, 1999). The levels of incomes for most of fish dealer's are very low (LVEMP, 2000). The employment opportunities are decreasing over time (Jansen, 1997). The causal reasons of these deficiencies are many.

Among them is ineffective involvement of local communities in the fishing industry.
From 1990s, involvement of local communities in the fishing industry has changed from traditional and subsistence level to an industry, characterized by a high level of commercialisation at both production and distribution (Jansen, 1997, Geheb, 1999). These changes have displaced local fisher folk and have reduced their capability to efficiently participate in the industry.

In order to increase capability of fish men and women, it is necessary to promote their involvement in the fishing industry. This is because participation generates effective returns on investment. For example, in 1998, the involvement of communities through district councils of Sengerema, Missungwi and Mwanza City council facilitated greatly the reduction of destructive fishing work (URT, 1999)..

As such, the objective of this paper is to identify factors influencing involvement of local communities in the fishing industry. It is expected that the highlighted factors will help local communities and policy makers, researchers and law enforcers to manage the lake by using established fishing policies, regulations and laws effectively. In all these aspects, it is assumed welfare of local communities will be raised through attaining their benefits and reward in the fishing industry.

Methodology

Research areas and selection procedure

The research covered Mara, Kagera and Mwanza regions. In these regions, districts were selected using simple random sampling. Geita, Mwanza and Magu districts were selected from Mwanza region. Bukoba and Biharamulo districts were selected from Kagera region while Bunda and Tarime were selected from Mara region. The criteria was to select 2 districts per region but Mwanza had 3 three districts because it has more districts along the lake as compared to other regions.

Sample size

The sampling size was calculated using formula formerly adopted by Casley and Kumar (1988) and refined by Colman (1999). The formula is shown below.

$$N = [(Z * C) / X]^2 \quad (1)$$

Where

N= required sample size,

Z= the value of (Z - score of standardized normal distribution) the confidence level (preferred %) required in covering the population per beach.

C= the coefficient variation of the measured variable (calculated through dividing standard deviation by mean and then multiply by 100).

X= the required level of precision in percentages (taken from various empirical documents)

By substitution (equation 1)

When confidence level is 95%, Z = 1.96 (2- tail), C= 13%, X= 6 %

Finally, $N= [(1.96 * 13) / 6]^2 = 18.034$ respondents per beach. The estimate was rounded to 18.

On observation, the maximum interviewed respondents reached up to 18 but minimal dropped to 15 per beach and this was considered as a fair representative. The numbers of respondents per region are as shown in Table 1 and by districts are depicted in Table 2. Table I reveals that over two fifth of respondents came from Mwanza region and this is because the region possesses more districts as compared to other remaining regions. The total number of respondents was 432. District wise, the highest number of respondents came from Magu (70) and lowest from Biharamulo (56) (Table 2).

Table 1: Total number of respondents by region

No	Region	Total respondents	%
1	Mwanza	191	44.21
2	Mara	126	29.17
3	Kagera	115	26.62
Total		**432**	

Source: Research survey 2000/01

Table 2: Total respondents by districts

Regions	**No**	**Districts**	**Respondents**	**%**
	1	Tarime	59	13.7
Mara	2	Bunda	67	15.5
	1	Magu	70	16.2
Mwanza	2	Mwanza	59	13.7
	3	Geita	62	14.4
	1	Biharamulo	56	13.0
Bukoba	2	Bukoba	59	13.7
Total	**7**		**432**	**100**

Source: Research survey 2000/01

Tools for data analysis

The collected data have been analysed using descriptive statistics, logistic regression models, linear regression and correlation method. These were preferred because they are efficient and enable interpretation of socio-economic data precisely.

(i) **The descriptive statistics**. This comprises of frequencies, cross tabulation and percentages. The tool is affirmative for general comparison of different variables or variation of events. It is widely used in computation of various categories and shows easy interpretation of the results. It is suitable in this study because it helps to distinguish the groups.

(ii) **Correlation analysis**. The method shows relationship between two different variables. The correlation may be negative or positive. The tool is useful as it helps to verify whether relationship between two variables exists, as well as indicating the magnitude of the correlation. Low correlation means poor relationship and vice versa. Its modes of operation are simplified below. However, applied in few cases in this content.

$$\mathbf{Y} = \sum_{i=1}^{n} \boldsymbol{\beta} \mathbf{X}_n \quad (2)$$

Where

Y= dependent variable

X_n= nth independent variable

β= coefficient of the variable X

(iii) **Simple linear regression model**. The model tests strengths of explanatory factors on the dependent variable. It is useful because its products show the implications of the system. The frame of the model is shown below but used only in specific areas.

$$\mathbf{Z} = \mathbf{b} + \sum_{i=1}^{n} \mathbf{e}\mathbf{K} + \mathbf{f} \quad (3)$$

where

Z= dependent variable,

K= independent variables,

b= constant term,

f= error term,

e = regression coefficient of variables K

(iv) **Logistic regression model**. This model operates as linear regression but differs on the value of dependent variable. Its dependent variable must be in binary values (either 1 or 0) (Gujarati, 1995). The values are obtainable on two ways, either transforming the old dependent variable values into new codes or may be they are in binary terms. It uses the principle of probability. Its design is as shown down.

$$\mathbf{prob}[\mathbf{P}(1-\mathbf{P})] = \mathbf{m} + \sum_{i=1}^{n} \mathbf{d}_n \mathbf{R}_n + \mathbf{w} \quad (4)$$

Where

P= probability of participating in fishing industry (production, processing and trading)

R= independent variables (continuous or binary ones), m= constant term, w= error term, d= regression coefficient of independent variables.

Results and discussions

Factors influencing fish producers

Descriptive statistics show 35 out of total 194 respondents replied that they had ability to fish while 159 or 82.0% had no ability to fish. Although small proportion of fish producers had ability to fish, logistic model finds that FABILITY (Fish Production Ability)was significant ($p<0.10$) factor which influences involvement in fish production. The finding is correct since ability shows various issues like experiences, skill and capability. Another factor was HHSIZE (Household Size), which influenced positively the involvement of local communities in fish production and significant ($p<0.05$). In a sample of 416 respondents, the mean of household size was 7.50 where by minimum was 1 and maximum was 45 people. Household size being significant is a rational behaviour since large households are able to provide necessary labour force. Although factor was DISBCH (Distance from Beach to nearest town), as it influenced involvement in fish production, it was insignificant factor. Survey in 376 respondents, found that average distance was 25 Km. The furthest distance was 123 km and the shortest being 1 km (Table 22). Rationally, the shorter distance from the beach would be expected to influence more involvement in fish production than far distance from the beach. This is because transport costs and marketing problems are easily controlled.

On the other side, factors such as RESTB (Respondent Tribe), DPDNOS (Dependants numbers), RESAGE (Respondent Age), EDLEVEL (Education Level), and DISTNM (District Name) decrease the community involvement in fish production. The tribe decreases and significant at 0.05 levels. Despite the significance of the tribe, its correlation coefficient is not appealing, as it has approximately 0.2259. Proportionally, Sukuma are majority in the survey area, followed by Haya, and third is Jita (Table 23). Regardless of tribe significances, some tribes may have more experiences in fishing activity than the others. This experience may be traced from their ancestors or family. For example, fish dealers who have been devoted in fishing production for long years would automatically be more acquainted than a colleague who is knowledgeable for short period.

The next factor is the dependant numbers in the household (DPDNOS), which is significant at 0.10 levels. Its correlation coefficient is 0.2228 and generally low. Survey found that average number of dependants in the household was 6. The minimum was 1 and maximum was 44.

The role of education in fishing production has been minimum. This was due to the fact that over 80% of total respondents (N=431) possessed educational level not more than standard seven. In this case, about 12.3% had finished form four levels. Due to this shortfall, Levinger and Drahman (1980) study observed that less educated people lack confidence in their ability to perform any activity. Education cannot be ignored. As Nanai (1993) argues that education may promote community participation in development projects. She considers education as the basic factor for participation in community development activities. Surprisingly, in the present study educational level neither influence community participation nor correlates with fishing aspect. The correlation coefficient of education level and fishing industry was found to be zero (R=0), which means there are no correlations between participation in fishing and education level. education level and district location are insignificant.

Survey of 432 respondents found that average age of communities involved in fishing industry is about 35 years. The minimal was 17 and maximum 79 years. It reflects the sensibility of fish production, which employs reasonable age of labour forces in the community. Similarly, Nanai (1993) found that the role of youths in community participation was more important than the elders. The low standard error of mean (0.48) explains that the calculated mean is a fair central tendency of the distribution. Results of logistic regression model for involvement of local community in fish production is as below.

Variable	B	S.E.	Wald	df	Sig	R
RESAGE	-0.1151	0.0806	2.0391	1	0.1533	-.0222
RESTB	-0.4850	0.1973	6.0433	1	0.0140**	-.2259
EDLEVEL	-1.0559	0.8454	1.5599	1	0.2117	.0000
HHSIZE	1.6174	0.6072	7.0952	1	0.0077**	.2536
DISBCH	0.0554	0.0348	2.5286	1	0.1118	.0817
FABILITY	2.2264	1.3091	2.8924	1	0.0890*	.1061
DPDNOS	-1.0887	0.4470	5.9328	1	0.0149**	-.2228
DISTNM	-0.8242	0.5138	2.5731	1	0.1087	-.0850
Constant	8.0606	4.4353	3.3028	1	.0692	

Note: Statistical significance of regression coefficients is as follows: **=p<0.05, *=p<0.10

Source: Research survey 2000/01

Where, B= regression coefficient, S.E= standard error, Wald = measuring t- test, sig = significance levels, R= coefficient of correlation

The summary of the model is shown as follows.

Involvement in fishing industry (producers)= 8.0606 - 0.1151RESAGE -.4850 RESTB - 1.0559EDLEVEL + 1.6174HHSIZE + 0.0554DISBCH +2.2264 FABILITY -1.0887DPDNOS - 0.8242 DISTNM

Factors influencing fish processors

Out of total respondents (N-83), 68.7 or 57 respondents replied that they use smoking for processing fish while 12% or 10 respondents use salting or sun drying and 19.3% or 19 respondents use frying. Experience shows that low-income fishers practice smoking method. Given that they lack capital, possibility of adopting modern techniques is very merge and therefore involvement in fishing processing is based on capital.

Logistic regression model found that household size (HHSIZE), distance from beach to nearest town (DISBCH) and processing ability (PROABL) are factors that influence positively involvement of local communities in fish processing. Household size was significant (p<0.10) but has a minimal correlation coefficient (0.1465). Distances from beach to nearest town and processing ability are insignificant and have no correlation with fish processing.

Respondent age (RESAGE) influences negatively and significant (p<0.10). Respondent tribe (RESTB) influences negatively but insignificant. Educational level (EDLEVEL) influences negatively and insignificant, number of dependents (DPDNOS) influences negatively and significant (p<0.10) and district name (DISTNM) influence negatively and significant (p<0.10). Fish processing model is illustrated below.

Variable	B	S.E	Wald	df	Sig	R
RESAGE	-.2159	.1286	2.8201	1	.0931*	-.1428
RESTB	-.3617	.3326	1.1827	1	.2768	.0000
EDLEVEL	-.4670	1.0600	.1941	1	.6595	.0000
HHSIZE	4.9201	2.9075	2.8635	1	.0906*	.1465
DISBCH	.0062	.0431	.0206	1	.8859	.0000
DPDNOS	-3.9352	2.3405	2.8271	1	.0927*	-.1434
DISTNM	-2.3455	1.2366	3.5977	1	.0579*	-.1993
PROABL	1.6588	1.3114	1.6000	1	.2059	.0000
Constant	13.9173	8.5473	2.6512	1	.1035	

Note: Statistical significance of coefficient regression, *=p<0.10

The equation of the model is expressed below and dependent variable. = INVO= involvement in fish processing.

INVO=13.9173 -.2159RESAGE-.3617RESTB- .4670EDLEVEL + 4.9201 HHSIZE + .0062 DISBCH -3.9352 DPDNOS -2.3455 DISTNM +1.6588 PROABL

Factors influencing fish market

Description statistics show that three fifth (60.8%) of total respondents (148) were fishmongers. Most of fishmongers were local communities who operated in low-income business. They operate in small-scale levels, as they cannot compete with non-fishmongers who manage large-scale basis.

Moreover, 53% of total respondents (83) sold fish directly to local consumers. Non-local consumers were factory agents, other regions and market outside Tanzania. They accounted for 47% of total respondents. Breakdown, 6.8% of all respondents are factory traders who are in export market. They are specializing on Nile perch *Lates niloticus* while small fishmongers are left with sardines (R*astrineobola argentea).* The Nile perch is potential as far it has a wide market internally and externally (Gibbon, 1997). The market is advanced such that local sellers left with narrow opportunity to survive. This is because they are unable to compete with exporting companies for the fish production and marketing (Mitullah, 1996; Jansen, 1996; Gibbon, 1997).

For instance, managerial capabilities (Hisrich, 1986) or reactive to market signals (Binks and Vale, 1990) are important skill which is associated with knowledge. As such, local communities participate at low level because they lack basic enterprises.

The factors that influenced positively the involvement of local communities in fish market include RESSEX (Respondent Sex) but not significant. MSTATUS (Marital Status) and not significant. Others are DISBCH (Distance from Beach to nearest town) but not significant. HHSIZE (Household Size) and significant ($p<0.01$).

Factors influencing participation but negatively include age, tribe, educational level, number of dependants and district location. In these factors, number of dependants and district location were more significant on reducing the participation in fish trading ($P<0.01$). Age RESAGE (Respondent Age) was also significant ($p< 0.05$) but educational level was insignificant. It was not normal as education was not supporting participation in fish trading.

The equation of the model is expressed below.

Involvement in fish trading = -7.0201 RESAGE-.1553 RESTB-.3080 EDLEVEL + .9234 HHSIZE + .0176 DISBCH -.6045 DPDNOS-.5846 DISTNM + 7.1853 RESSEX + 6.1698 MSTATUS.

Dependent Variable is INVO, which means involvement in fish trading. INVO takes the value of 1 if a respondent is involved in the fish trade, 0 if he/she is not involved.

The result of the model is as follows.

Variable	B	S.E.	Wald	df	Sig	R
RESAGE	-.0696	.0298	5.4692	1	.0194**	-.1416
RESTB	-.1553	.0845	3.3784	1	.0661*	-.0892
EDLEVEL	-.3080	.3306	.8680	1	.3515	.0000
HHSIZE	.9234	.2239	17.00451		.0000***	.2944
DISBCH	.0176	.0147	1.4306	1	.2317	.0000
DPDNOS	-.6045	.1878	10.36751		.0013***	-.2199
DISTNM	-.5846	.1854	9.9462	1	.0016***	- .2143
RESSEX	7.1853	31.8002	.0511	1	.8212.	.0000
MSTATUS	6.1698	25.8904	.0568	1	.8116	.0000
Constant	-7.0201	41.0347	.0293	1	.8642	

Note: Statistical significance of regression are ***=p<0.01, **=p<. 05, *=p<0.10

Source: Research survey 2000/01

Regardless of the findings, business is done due to basic motivation. As motivation for business growth cannot be assumed (Levie and Hay, 1998), it is positively correlated with business survival (Bridge *et al*. 1998). It implies fish trade is continuing developing since it gives livelihood to the owner. However, change of economic status of the society is likely to influence trade positively or negatively (Vyakarnam, 1999).

In addition to economic status in the business, other factor may be influencing to successes in trade. For instance, Alila and McCormick (1997) found that collaboration and frequent contact with large firms in the same line of Kenya's tourist businesses lead to faster business growth. Yet, Llewllyn (1994) cited by Kimeme (2001) observes that by behaving as outsiders to the community, some Sri Lankan traders distanced themselves from their customers and this enabled them to control the interaction between their social and business relationships to their economic advantage. Relatively, during the survey in beaches in Mwanza, Mara and Kagera, the same principle was noted as happening. Most of trader's especially factory agents were not cooperating or being closers to sellers. This may be due to some hidden agenda. The agenda is not known but price offered by factory agents was considered low and complain was not addressed by the concern. Who is the concern? The decision makers are to be blamed. Beside that Menkhoff (1994) observed further, that Chinese traders in Singapore deliberately cultivated trust with their trading partners and that trust was the single most frequently mentioned factor in connection with trading success.

Conclusion and recommendations

Conclusions

(i) Significant factors that influence positively the community participation in fish production are ability to fish and household size. However, factors that are significant but influence negatively community participation in fish production include tribe and number of dependents in the household. Educational level does not influence community participation and the reason for this outcome needs more investigation. Nevertheless, one can conclude that the present state of affairs in the fishing community is associated with the low education level among members of the community. It implies that educational level is not a factor that influences much participation in fishing.

(ii) It is concluded that household size, processing ability and distance from beach to nearest town influence greatly community participation in fish processing. The most effective factor is household size, which is significant ($p< 0.10$). The age, dependency numbers and district location are also significant but influence participation inversely. The education level and tribe negatively influence participation, however are not correlated to fish processing.

(iii) Household size, distance from the beach to nearest town, gender, and marital status plays an important role on influencing community participation in fish trading. However, household size is significant ($p<0.05$) while other 3 factors are insignificant. Factors such as age, tribe, educational level, number of dependants and district location do discourage participation and all of them except education are significant

Recommendation

Ability to fish, to process and to market are basic features which promote involvement of local communities in fish industry. This factor must be considered in order to improve fish industry. The consideration may include to provide essential improved facilities such as fishing gears, reliable processing technologies and educating the dealers on how to manage good enterprises. Distance from the beach to nearest town has been identified as the important criteria of involving the communities in the industry. The best way is to improve transport infrastructures, especially roads. Although education is not playing the best role in influencing the communities, it worth to educate the communities on how to be effective by adopting the improved technologies. This could be associated by involving the local communities on managing the lake, modifying the established policies, regulation and laws.

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Fish Quality Assurance at Landing Beaches and During Transportation to Fish Processing Plants

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Abstract

Fish contamination, fish spoilage and post harvest losses were identified as major problems affecting fish trade in Lake Victoria. This paper summarizes efforts which have been made to improve fish quality before reaching fish processing plants i.e. during fishing, landing and transportation. Fish landing systems have been improved to include in water fish transfer, beach landing racks and floating barge. These measures have almost eliminated fish contamination during landing. The design and usage of these methods are elaborated. The paper identifies current fish transportation deficiencies and advises on appropriate measures to improve performance, setting of technical standards and areas for technology transfers.

Key words: Fish Landing, Floating Barge, Fish Racks, Collection Boats, Insulated Containers.

Introduction

The majority of fishing vessels in Lake Victoria are planked non-motorized canoes, typically 5-9 meter length. Fishing is a night operation and most of the fishermen use gillnets or long lines. Fishing gears are set in the evenings and hauled in the early mornings. The 10-12 hrs interval between setting and hauling the gear results in spoilage of some fish. Almost all catches on board the fishing vessels for all seasons contain some spoiled fish, irrespective of season. Nanyaro and Makene, (1998), tentatively estimated net spoiled Nile perch to be over 18% during the hot season. They also identified the fish landing environment to be the major source of fish quality problems. Water quality at fishing villages and camps is poor and the beaches are crowded with small, poorly constructed mud and grass thatched huts, contributing to an unhygienic environment.

Efforts to improve Lake Victoria Nile perch handling before it reaches the fish processing plants were started in the early 1990`s. FAO, under the cooperative adaptive Research Programme (1993), contracted the Kenya Marine and Freshwater Research Institute, Kisumu Laboratory KMFRI), Kenya (; Nyegezi Freshwater Fisheries Institute (NFFI), Mwanza, Tanzania, Entebbe Fisheries Institute (EFI), Entebbe, Uganda,; Mbegani Fisheries Development Centre (MFDC), Bagamoyo Tanzania, and the Institut de Technologie Almentaire (ITA), Dakar Senegal to develop appropriate insulated containers for Nile perch collection boats (Makene, 1996). The project gave birth to the now popularly known “kontena,” an insulated “v” shaped tailor made container, a design adopted from Senegal`s “Ice pirogues”

Performance of these containers was studied by the Lake Victoria Environment Management Project (LVEMP).

In addition to Nile perch, the paper reports on the development work done on Dagaa. Dagaa is not yet processed in factories but this bound to happen in the future. Markets for well-processed Dagaa products are expanding, a number of investors are investigating the industry and the fishery has a commercial potential.

Material and methods

Multi-Hauling Fishing

Under the LVEMP, multi-hauling practice was recommended, to reduce fish spoilage during fishing. Experiments were performed over nine days, using three sets of gill nets. During fishing, all sets of nets were set in the evenings, at the same fishing ground and hauled at different times. One group of nets was hauled every four hours, while the other nets were hauled twice, at midnight and morning. The last set was hauled only once, in the morning. Catch from the fishing was assessed organolepticaly (Table 1)

Table 1: Nile Perch Quality Assessment Scheme

Grade	OUTER APPEARANCE					
	Skin	Gill colour	Gill odour	Eyes	Texture	Score
Grade A	Natural brilliance silver	Red, No slime	Fresh, water weeds neutral	Transparent, Convex	Firm elastic	9 8
Grade B	Grayish Loss of metallic shine	Bleached Have slime	Slight off Odours	Red Slightly milky flat	Soft	7 6 5 4
Grade C	Yellow Slime	Green	Strong off odour	Sunken	Soft sloppy	3 2 1

Fish Landings

To improve fish quality during fish landing, the LVEMP – Fisheries management component introduced three methods of fish landing;

- Transfer of fish from fishing boat to fish collection boat in offshore or inshore waters.
- Use of wooden constructed beach fish landing racks
- Use of a floating barge as a fish landing facility.

These measures ware introduced to eliminate dipping of clean fish in contaminated inshore waters. The traditional practice involved dragging fish through the beach shallow water and finally throwing it on the sand. The practice contaminates fish with bacteria, including pathogens.

Fish landing on fish collection boats

To facilitate the transfer of fish from fishing boats to fish collection boats, all fish collection boats were advised to construct a Biped or Tripod stand on their boat for hanging weighing scales (Fig. 1) for weighing fish during sales. On arrival at the fishing villages/camps, fish collectors ware advised to anchor their boats at a distance (5-10 meters) from the beach, away from the contaminated beach water. Fishing boats were advised to go along side the fish collection boats. A reserved area for fishermen to directly transfer good quality Nile perch into the fish collection boats was established.

FIG. 1: Fish Collection Boat

FIG. 2: Floating Barge

Use of beach fish receiving racks

Beach Management Units (BMU), groups nominated by villages to manage beach activities were advised to construct fish landing racks made from available materials, which can easily be cleaned. Rack size depended on amount of fish landed.

Floating barge

To eliminate beach contamination during fish landing, LVEMP introduced floating barges to be used as landing jetties. In designing the barges, the following parameters were taken into consideration: -

- Capacity for Nile perch landing/beach/time
- Number of fish collectors at a point/time
- Fish collection boats – sizes and design
- Fishing boats – sizes and design
- Topography of the landing beaches
- Weather and wind effects
- Approved stability
- Acceptable rolling and pitching
- Self propelling with outboard engine or towed
- Available local material
- Reasonable cost
- Easy maintenance

Fish Collection Boats

A field study was conducted to study the performance of the prefabricated, tailor-made insulated containers. Informal interviews were conducted with fishermen, fish collectors and boat owners.

Dagaa Processing

Work to improve hygienic practices concentrated on improving Dagaa processingtechniques. Appropriate kilns and drying racks were constructed (Fig. 3) and drying techniques demonstrated.

Results and discussions

Multi-hauling

TABLE 2: Single and multi hauled catches quality assessment

	Hauled in the morning	Hauled Midnight and morning	Hauled after every 4 hrs.
Total No. of fish	638	587	518
Total weight	1638	1564	1270
Weight accepted	1545	982	1271
% of rejects	5.7	7.1	7.2

Results of the multi-hauling experiments are summarized in Table 2. Fish hauled during the night had a lower score than those hauled in the morning. This was the opposite of what was expected. The fishermen did not use ice, and fish caught in the night were left at at ambient temperature and subsequently deteriorated. Total catch was affected by the multi-hauling practice, the greater the number of hauls, the smaller the catch. Fish LandingTransfer of fish in water

In areas sheltered from waves and wind, the transfer of fish from fishing boat to fish collector's boat was easy and acceptable. Many Fish collectors preferred the system, as it simplified fish handling work. They easily assessed the quality, weighed and iced the fish in the insulated container on board. Fishermen then continued to the beach to sell the rejected fish.

Fish receiving racks

Most villages constructed wooden or reed racks of one metre height, one and half metre width, and two to four metres length . In most villages, when a fishing boat arrives at the beach, fish carriers – popularly known as health officers, carry fish from the boat to the landing racks. These health officers are responsible for beach cleanliness and fish landing. The carriers use special baskets or wheelbarrows.

Sales are by auction or price negotiation. After the sales, the health officer clean the racks using water from off shores.

Floating barges

In designing the floating barge it was found that 12m x 5m x 1.2m was a suitable barge size, able to accommodate four fish collection boats ata time. Barges were constructed by Mwanza Boatyard and put in use as fish transfer platforms.

Fishing boats returning from fishing, go along one side of the barge, while fish collection boats operate on the other side. Four barges were made for Mihama, Ito, Nansio and Kayenze.

The barges were placed under the responsibility of Beach Management Units (BMU) of the area. The BMU had quality control and safety assurance guidelines from the competent authority of the Lake Zone Office.

The use of the floating barge became a breakthrough in fish handling because clean fish, caught in clean deep waters, remained clean all the way to the fish processing plants.

The use of the barges however, had some shortcomings namely;

- Number of fish porters on the barge per fish trader were high, resulting in over crowding.
- A few fishermen had a tendency to remain on the barge after sales, increasing over crowding.
- Some fish traders/agents kept several insulated containers on the barge further reducing the available space.
- It was difficulty to use the barge during strong winds.
- There was no provision of a portable water system for washing the barge and the fish handling facilities after use.

Fish Collection Boats

The study on fish collection boat revealed the following problems:

- There was rampant use of wrong size containers,
- Inappropriate insulation materials were used,
- In some cases very thin insulation materials were used,
- In some other cases there was absence of insulation materials
- Some containers had connected inner and outer lining made of galvanized iron sheets, thus conducting heat from outside to the inside of the containers,
- Unsuitable inner lining materials were used
- There were no drainage holes at the bottom
- Wrong door size was used
- Unsealed inner lining surfaces
- Unprotected outer surfaces
- There was no front – rear elevation thus retaining splashed water

Table 3: Comparison of 10 Fish Collection Boats Landings (1998)

No:	Boat size (meter)	Container capacity (tons)	Period month	No. of landing	Total wt. kg	Wt. rejected kg	% of reject
1.	13.4	11	Feb-Dec	36	250474	12558	5.0
2.	14.0	11	Feb-Dec	27	201674	12793	6.3
3.	14.0	8	Feb-Dec	29	133036	8851	6.7
4	11.0	8	March-Dec	27	149855	10615	7.1
5	11.0	7	Feb-Dec	30	131643	10646	8.1
6.	12.5	6	Feb-Dec	27	127895	9931	7.8
7.	10.7	5	Feb-Dec	3	143053	5434	3.8
8	10.2	5	Feb-Dec	41	131284	6269	4.8
9.	10.0	4	March-Dec	23	44083	1565	3.6
10.	9.3	2	May-Dec	27	41743	1374	3.3

The effects of using a big container and less ice are shown in Table 3. This data originates from 10 fish collection boats, selected randomly among 25 boats of similar size, supplying fish to one Mwanza fish processing plant. As can be seen from the table the bigger size containers (capacity > 5 tons) had a bigger chance of landing higher percentages of fish rejects (>5.0%). There was though no direct correlation between the actual size and rejects indicating that other factors might be playing a role too. The role of container size may be due to frequency of opening of the container which increases the rate of melting of ice, longer collection days surpassing shelf life period, and fish at he bottom of the container being squashed by overlying fish. Boat No. 6 had the highest reject value. The boat is a good example of the effect of using less ice. The average weight of fish carried per trip was 4737 kg. The container capacity was 6,000kg. That means only 1363 kg space capacity was left for ice or an icing ratio of 0.29:1. The best icing ratio is 1:1 (ice: fish**).**

Apart from these technical faults, it was found that delay in icing was one of the factors contributing to high rejection rates.

The rectification of these technical faults, were included in the one-day technical workshop for carpenters engaged in container construction, boat builders and fish traders funded by LVEMP (August 1999). On a separate initiative, NFFI conducted short courses to fish traders, fishermen, youths and women. These efforts have had a significant impact on improving the quality of Nile perch.

Dagaa products

Products from the racks (Fig. 3) proved to be of high quality, very clean, without sand and with shining colour. Most of the processed Dagaa remained round an attractive shape.

Figure 3: Drying Dagaa at Ntama Beach, Sengerema District

Conclusions and reccommendations

- Fishermen contribute significantly to the National Economy. Like any other income generating groups they need to be given an opportunity to improve their social welfare. Fishermen's earnings are much higher compared to farmers. Given appropriate opportunities they will improve their present hygienic standards. This would improve hygienic environment were fish are landed.

- Experiments on multi-hauling practices and procedures were not followed up. More work should be done in this area to establish appropriate hauling time during warm and cool seasons and optimum time for leaving the nets in the water.

- By using ice onboard fishermen will improve the quality of fish. Fishermen should be encouraged to use ice in the ratio of 1:1 (1 kg of ice: I kg of fish) and small insulated containers of one ton capacity to minimize fish contamination and deterioration while on board a fishing vessels.

- The use of floating barges for fish landing was demonstrated to be a solution of poor fish handling during fish landing. More barges should be constructed at least 5 barges per District. The barges should be installed with a reliable supply of portable water. This will improve further the hygienic standards.

- Fisheries Division should introduce standards for fish collection boats and fish insulated containers, in terms of size, design and materials. Long narrow boats of 6-8 tons capacity, with a short draft, where fish can be iced while standing on bottom planks are ideal. Fish containers of 2-3 tons capacity, made of easy cleaned, non-corrosive materials, with appropriate insulation materials of not less then 5 cm are recommended.

- Fisheries Division should prepare a training program, train and distribute training materials for fish handling, processing, fish quality control, safety assurance, appropriate design for fish collection boats, insulated containers, fish preservation by using ice, etc. The training materials can be in form of manuals, pamphlets, and brochure in Kiswahili for fishermen, fish processors, and boat builders and fish traders.

- Demand for of ice for fish icing is far beyond the present urban supplies. Ice availability needs to be increased in fishing areas. Efforts to use solar power and wind power to produce ice should be encouraged. Fisheries Division should promote investments in ice production plants.

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SUMMARY

Lake Victoria is very important to the economies of the East African Community Partner States. The fishery has undergone major transformations since fish catches increased following establishment of Nile perch (*Lates niloticus*) and emerging fish processing plants, which export fish and fish products. Fishing pressure on the lake increased rapidly creating fears that the fishery may not be sustainable. Frame surveys have been carried out on Lake Victoria biannually since 2000 to determine the number of fishers and fish landing sites, facilities at the landing sites, the types, numbers and sizes of fishing crafts and their mode of propulsion, the number, types and sizes of fishing gears and the fish species targeted to provide information to guide development and management of the fishery. The surveys show that: the number of fishers and fish landing sites did not change significantly between 2000 and 2004; there were inadequate facilities at the fish landing sites; the total number of gillnets increased from 650,653 in 2000 to 984,084 in 2002 and 1,233,052 in 2004 suggesting an increase in fishing effort. The number of fishing crafts using outboard engines increased from 4,108 in 2000 to 6,552 in 2002 and 9,609 in 2004, suggesting that fishers went far in search of fish. The Partner states have made deliberate efforts to improve facilities at fish landing sites to meet fish quality requirements and curb illegal fishing gears which is manifested in the reduction in the number of beach seines and illegal gillnets of prohibited mesh sizes. However, there were still a large number of illegal gears especially beach seines and gill nets of mesh sizes less than 5 inches. Facilities and access to fish landing sites should be improved. Efforts to remove illegal fishing gears and methods should be enhanced; and fishing effort should as much as possible be moderated.