IUCN Eastern Africa Programme

Socio-economics of the Lake Victoria Fisheries

A REVIEW OF BIODIVERSITY AND SOCIO-ECONOMICS RESEARCH IN RELATION TO FISHERIES IN LAKE VICTORIA

Okeyo-Owuor J.B.

Report No. 5

May 1999

IUCN
The World Conservation Union

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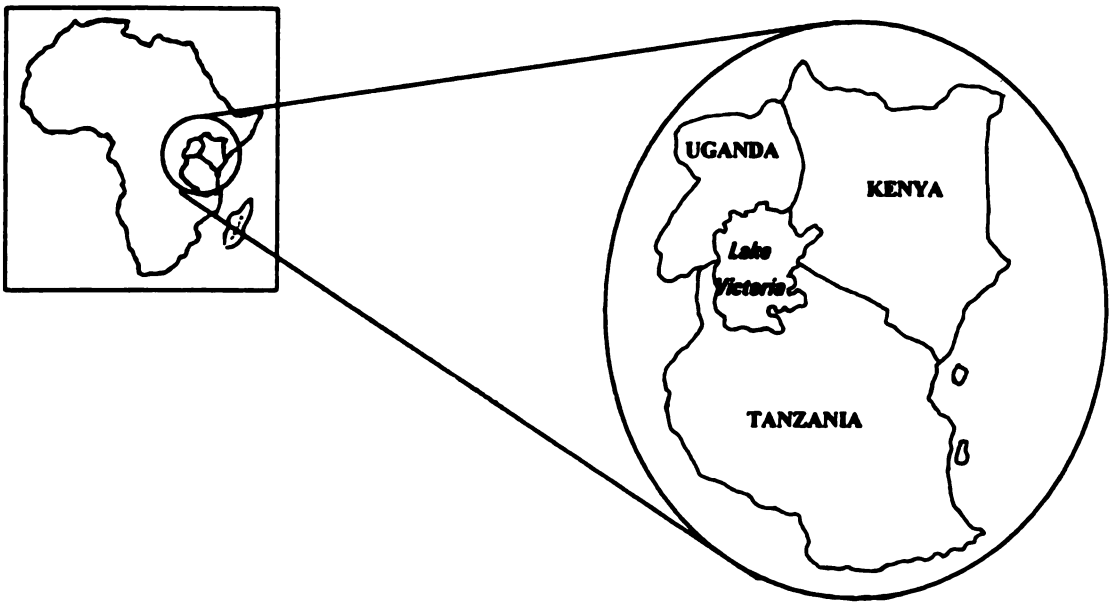

Lake Victoria is the second biggest fresh water lake in the world. With its 69,000 km^2, the lake has the same size as Ireland. The lake is shared between three countries; Tanzania (which possesses 49%), Uganda (45%) and Kenya (6%) of the lake.

The findings, interpretations and conclusions in this publication are those of the author and do not necessarily reflect those of IUCN or the partner organisations in this project.

Cover photo: Immature smoked Nile perch ready for market. As adult fish goes for export, local consumers remain with immature fish.

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Table of Contents

PREFACE iv

EXECUTIVE SUMMARY v

ACKNOWLEDGMENTS vii

1. INTRODUCTION 1

2. OBJECTIVE 2

3. APPROACH AND TECHNIQUES 2

4. BIODIVERSITY RESEARCH ON LAKE VICTORIA 3
- 4.1. Overview 3
- 4.2. Fish Species diversity and Population abundance 3
- 4.3. Fish Communities and changes in population and diversity 5
- 4.4. Other vertebrates 9
- 4.5. Invertebrates 9
- 4.6. Plants and Micro-organisms 10
- 4.7. Ecosystems diversity 10
- 4.8. Biodiversity Conservation in Lake Victoria 11

5. SOCIO-ECONOMIC RESEARCH AND BIODIVERSITY 12
- 5.1. Socio-economics of fisheries species diversity 12
- 5.2. Socio-economics of Nile perch fisheries and recent changes 13
- 5.3. Socio-economic impacts on other biodiversity 15

6. INSTITUTIONS WORKING ON LAKE VICTORIA FISHERIES 15
- 6.1. Governmental institutions 15
- 6.2. Non-Governmental and international Organizations 18

7. KNOWLEDGE GAPS AND AREAS FOR FUTURE RESEARCH 19

8. CONCLUSIONS 22

LIST OF REFERENCES 23

PREFACE

During the last 20 years, a great deal of attention has been paid to the Lake Victoria fisheries. Both national and international organisations have been conducting research on the development trends in the fisheries resources of the lake. More recently, two large development programs supported by the World Bank and the European Union have been launched to promote policies to encourage a more sustainable exploitation of the lake's fisheries resources.

Much of the attention on the Lake Victoria fisheries is linked to the introduction of the Nile perch in the 1950s and the effects this caused two to three decades later. A major effect was the transformation of the fisheries from a broadly based multispecies fishery to one based on three dominant species; a small sardine-like species, *Rastrineobola argentea*, Nile Tilapia *(Oreochromis niloticus)*, and the Nile perch, (*Lates niloticus)*. Lake Victoria has become famous for the loss of an estimated two thirds of its endemic cichlid fish species. With the dramatic decline in species, there was a simultaneous phenomenal increase in the total annual fish yield; from about 100,000 tons annually in the 1960s and 1970s to 500,000 tons in the late 1980s and 1990s. The major socio-economic effect of the introduction of the Nile perch is the transformation of the fisheries from a local and regionally based fishery to one closely integrated into the global economy.

Much research has been conducted on the changes in biodiversity, the impacts on the general ecology of the lake in the last decades, and the socio-economic changes that have occurred. The research on these themes has been conducted by many national, regional and international institutions. It is sad to note, however, how little known much of this research is to the institutions and persons engaged in both the management and research of the Lake Victoria fisheries.

This report attempts to begin to remedy this situation. From his vantage view at the School of Environmental Studies at the Moi Universiy, Dr. Okeyo-Owour reviews a number of the studies which have been carried out on the recent changes in the Lake Victoria fisheries. He also lists a number of institutions which are engaged in research and management in this field. This review is not meant to be comprehensive, and there is no doubt that may useful research reports have not been dealt with in this study. Nevertheless, we feel that it is a useful contribution to the study of Lake Victoria, and will stimulate further work and a more comprehensive survey of literature.

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EXECUTIVE SUMMARY

This document is a consultancy report on the past, present and future biodiversity and socio-economic research, with emphasis on fishery resources in Lake Victoria. The report provides an account of different institutions, (particularly Kenyan), and individuals conducting research on the lake. It summarizes some knowledge gaps and suggests certain areas of interest for future research that would enhance conservation and sustainable utilization of the lake's biological resources. The report is organized into eight sections. Section one is a general introduction on the environmental issues and problems facing the Lake. This section provides some insight into the ecological changes to set the stage for reviewing the biodiversity and socio-economic research on the fishery and associated resources in the lake. Sections two and three discuss the objectives, approach and techniques used in this study. The main text of this report is in sections four, five and six. A review of the biodiversity research in Lake Victoria is given in section four. The section provides an overview of fish species, invertebrates, plants, ecosystems and looks at aspects of biodiversity conservation in the Lake Victoria. Section five focuses on research on socio-economics in relation to the lake's biodiversity. In section six a brief review is presented on the different national institutions and NGOs whose work is in one way or another related to both the biodiversity and socio-economics of the lake. This section focuses mainly on the Kenyan based institutions, although other regional and international institutions are also briefly presented. Section seven gives a summary of knowledge gaps identified during the study and recommendations for future research on the lake's biodiversity and socio-economics. A brief conclusion is presented in section eight, and two annexes presented at the end of the report provide a list of persons who have contributed to research on Lake Victoria's biodiversity and socio-economics.

The study was conducted between 27 July-15 September 1998 by reviewing available literature related to biodiversity and socio-economics of Lake Victoria from various sources. Various research institutions and NGOs were visited to gather data for this study, and literature reviewed. It is important to note that although much work is being conducted in Lake Victoria, this review focuses mainly on fish biodiversity and related socio-economic work. Despite the extensive amount of research recently carried out on the lake's biodiversity, studies on linkages between the socio-economical changes and the implications on biodiversity conservation have not always been adequately recognised and understood. However, due to the limited time frame during which this study was carried out and the extent of available literature; there is much existing literature of equal importance that has not been included in the final output of the review. Nevertheless, during the study limitations of current and past research became apparent, and are presented in this report as recommendations for future research.

Despite the fast declining rich biodiversity in and around Lake Victoria, there is no authoritative catalogue on the indigenous biodiversity in the region that would assist in continued evaluation of the status of the lake's biological integrity. Information is also lacking on possible bio-indicators in the lake, necessary for determining the nature and extent of ecological changes as a consequence of further degradation and/or conservation efforts. It was also found that there is little information on alternative energy sources for smoking fish. Such energy sources, if studied and developed, will reduce the over-exploitation of some indigenous flora in the lake region and possibly save them from extinction. Furthermore, the avian diversity in and around the lake is not yet investigated and reported. This information is essential as we seek to understand the changes in food chain and avian habitats which continue to be destroyed by human induced degradation of the lake's biological resources such as wetlands and associated vegetation. These ecosystems have acted as stable habitats and food sources for many bird species.

The ecosystem dynamics and prey predator interactions in the lake in relation to Nile perch feeding behavior and other human induced changes need to be investigated and monitored with respect to spatial and temporal variations. Furthermore, since the Nile perch is currently being over-fished, studies are necessary to reveal the changes in its population structure, diets and the impact on the diversity of other species.

Socio-economic research is necessary to examine in order to understand and report on the implications of over-fishing of the Nile perch and other tilapiine species which has intensified during the last 15 or so years. It is also necessary to investigate coping strategies of the local communities with respect to their income and protein sources, as well as the increased dependence on processed fish products and by-products, and consequent implications on current declining fisheries in the lake.

Although the wetland around Lake Victoria is today under human pressure and conflict as its biological resources continue to be over-exploited, socio-economic research in progress on the apparent changing status, uses and value of this valuable ecosystem is limited. Further research should be conducted on views and attitudes of indigenous peoples on biodiversity within fisheries in the wetland and open waters of Lake Victoria, to enhance conservation efforts.

In Kenya, there is a large amount of gray and preliminary data on biodiversity and socio-economics collected independently by different organizations. These should be examined, evaluated as to their significance and accuracy, analyzed and published. Despite the new efforts on the establishment of the East African Community, there are still gaps that hinder free flow of research information and networking between the different institutions and individuals working on biodiversity and socio-economics of Lake Victoria.

It may be concluded that although substantial research work has been done on Lake Victoria fisheries and socio-economics, there remains knowledge gaps in the research that aim to understand the linkages between social and economic development, biodiversity conservation and the sustainable use of natural resources.

ACKNOWLEDGMENTS

I wish to acknowledge the International Union for Conservation of Nature (IUCN) who commissioned this work and funded it. In particular I am grateful to Dr. Eirik G. Jansen and Dr. Geoffrey Howard of IUCN for their initial input and contributions into this report. I also wish to thank Ms Mine Pabari for her assistance with logistics and encouragement during the work. This work would not have been well done without the input of my research assistant, Mr. Zack Otieno Ayayo, whose assistance in gathering the necessary data for this report I sincerely acknowledge. Both Mr. J.O. Manyala and Mr. P.O. Raburu of Fisheries Department, Moi University, assisted in giving various scientific information and literature and I wish to thank them all. I thank all the individuals and institutions who voluntarily gave information to me. In particular I wish to acknowledge the contribution of Kenya Marine and Fisheries Research Institute (KMFRI) and its scientists for all the scientific assistance I got during my various visits and at the Socio-economics and Biodiversity seminar held in Rongo (27-30 July 1998), where I got substantial amount of information.

Fishermen display their catch of Nile perch. The fish catch per boat is on the decline

1. INTRODUCTION

The African Great Lakes are considered to be dynamically fragile ecosystems that are relatively resistant to minor changes with which they have co-evolved but vulnerable to major perturbations such as overfishing, the introduction of alien species and pollution. Lake Victoria is the second largest fresh water lake in the world and the largest of its kind in Africa. The lake is rich in biodiversity, of which fisheries is a major resource for the riparian communities and for export. During the last two decades the lake has encountered numerous problems and extensive resource exploitation which has constrained its productivity resulting in the drastic decline of biodiversity in general and fisheries in particular.

Since 1920s the lake has undergone successive dramatic changes. Intensive non-selective fisheries, extreme changes in the drainage basin vegetation, industrialization, agricultural developments, dams and the introduction and invasion of exotic species are among the factors that have led to the destruction of the native and endemic components of the lake. These have been followed by a progressive build-up of physical and chemical changes in Lake Victoria. For instance, to date there are substantial increases in the chlorophyll concentration and primary productivity as well as decreases in silica and sulphur concentrations compared to values measured 30 years ago (Hecky, 1993). Other evidences in the ecological changes of community towards dominance of blue-greens and an enhancement of algal blooms. In some shallow depths of the lake anoxic waters have recently been found suggesting significant increases of oxygen demand in the seasonally formed hypolimnion, (Ochumba, 1990). This situation has increasingly resulted in the impoverishment of the lake. The lakes ecosystem has also been particularly affected by the introduction of the Nile perch, *Lates niloticus* during 1950s and the water hyacinth, *Eichhornia crassipes* in 1990s, the consequence of which are detrimental to the lake's biodiversity, especially fish; leading to a shift in the fishery from a multi-species to only two major exotic species, *Lates niloticus* and *Oreochromis niloticus* and the endemic species *Rastrineobola argentea* (Ochumba *et al* 1991).

The endemic species fish and bird flocks found in Lake Victoria are today threatened by a variety of human activities. The 1988 World Conservation Union Red Book of Endangered Species listed hundreds of endemic fishes of Lake Victoria as endangered. Scientists, fishermen, and environmentalists have decried the loss of Lake Victoria's native species, while others have praised the introduction of Nile perch, some even referring to it as a 'savior'(Gibbon, 1997). Now the savior threatens to destroy itself, the lake ecosystem, and a major source of protein in the midst of the world's fastest-growing human population. More than thirty million people who depend on the lake are

feeling the consequences of these changes in the biota and lake environment. In Lake Victoria, as elsewhere, human welfare is intimately linked to concerns for species conservation and ecosystem integrity (Kaufman *et al* 1992). At the moment many fish communities of Lake Victoria are being intensively exploited to meet escalating needs for animal protein, the requirement of which is rising exponentially with the rapidly accelerating increase in human populations. However, there is sometimes only partial appreciation of the very important role which fisheries economics as a discipline can play in the unraveling of the internal workings of fishery systems.

O'Riordan (1996) argued that management of Lake Victoria's fishery resources is in need of reform to prevent a collapse in fisheries, local economies and environmental degradation. This role extends to the formulation of management, development and research strategies, the assessment of the impact of intervention measures and so on. In a review of fresh water biodiversity Stiassny (1996) observed that as the twentieth century draws to a close, the management of freshwater usage and aquatic conservation is perhaps more urgent than development effort in the world. He argued that as human populations continue to increase, the limits of the earth's freshwater resources are revealed more and more in the increasingly intense conflicts between human consumptive usage and the maintenance of aquatic health and biodiversity. However, it is increasingly evident that the pending "crisis of freshwater" will set the agenda regarding future development (Stiassny 1996). The Lake Victoria situation is already on the worse side of environmental degradation and biodiversity loss and has attracted substantial international attention.

2. OBJECTIVE

The overall objective of this study was to evaluate, analyze and report on the past, present and future biodiversity research in relation to fisheries in Lake Victoria with special reference to socio-economics.

3. APPROACH AND TECHNIQUES

This study was conducted between 27 July and 15 September 1998. The approach to the study was two fold. Firstly, a review was done on the literature available on the biodiversity and socio-economic studies on Lake Victoria. To achieve this, as much literature as possible was collected from institutions working on Lake Victoria. Computer search was also conducted to obtain published literature not found in the institutions. Secondly, a list of the different institutions working on Lake Victoria was obtained and some of them visited to obtain information from related research projects and scientists working on the subject matter. Discussions were held with different scientists working on biodiversity and socio-economics of Lake Victoria. Due to lack of time these visits were only confined to the Kenyan based institutions, however, some valuable information on the work done in Uganda, Tanzania and other institutions out side the region was obtained and applied in this report. The study concentrated mainly on previous research and publications and current research work on Lake Victoria. Both published and row (gray) data obtained were examined. The data obtained was used to compile this report to meet the following agenda for the study:-

1. To investigate and catalogue the various institutions, projects and individuals conducting research work on biodiversity of Lake Victoria.
2. Review the previous and current research work and achievements on biodiversity in East Africa (especially Kenya) with special emphasis on the water, wetlands and fisheries in Lake Victoria.
3. Study and review the various socio-economic aspects of fisheries related to biodiversity studies in Lake Victoria.
4. Identify and report on gaps related to research in socio-economic aspects of biodiversity in Lake Victoria.
5. Investigate and report on any future work necessary for biodiversity in relation to Lake Victoria fisheries with emphasis on the socio-economic aspects.

With the aid of one research assistant the following institutions were visited Kenya Marine and Fisheries Research Institute (KMFRI, Kisumu), Kenya Medical Research Institute (KEMRI, Kisumu), Moi University (School of Environmental Studies and Department of Fisheries), Nairobi University (Department of Zoology), Department of Fisheries (Kisumu), National Museums of Kenya (Nairobi), Kenya Wildlife Services (Biodiversity-Nairobi and Kitale), International Union for Conservation of Nature (IUCN, Nairobi and Kisumu), Friends of Lake Victoria Environmental Program (OSIENALA), Maseno University College (CSOLVE), Intermediate Technology Development Group (ITDG, Kisumu), Nyando Wetland Conservation Program (Ahero-Collaboration KWS and Moi University), Industrial and Technology

Engineering Trust (ITET-Kisumu), Lake Victoria Fisherfolk Associations, KENGO - Uhai-Lake Region Program (Kisumu), One World Development Foundation (Busia), Gender Development Center (Kisumu), International Center for Development (ICD-Homa Bay), CARE Kenya (Agroforestry program). The proceedings of KMFRI's seminar on biodiversity and socio-economics held in Rongo, Kenya, also provided valuable information for this review.

4. BIODIVERSITY RESEARCH ON LAKE VICTORIA

4.1. Overview

Biodiversity may be defined as the totality of genes, species and ecosystems in a region also described as the degree of variability in nature expressed in the organisms such as plants, animals, fungi, microbes and the ecosystems of which they are part. Despite their relatively small sizes, only about 0.01% by volume of the earth's total water body available in rivers, lakes and wetlands (Watson *et al*, 1995), fresh water ecosystems such as that of Lake Victoria are rich in biodiversity. According to Groombridge (1992) all the major taxonomic groups which are likely to contain in excess of 100,000 species occur in fresh water. These include insects, arachnids, crustaceans, molluscs, nematodes, plants, algae, protozoa, bacteria and viruses. About 12 % of animal species are found in fresh water (Abramovitz 1996) and yet this ecosystem is the most threatened with environmental degradation in the world today.

Lowe-McConnell (1993) presented a good account of the origin, diversity and vulnerability of fish faunas of the great African Lakes including Lake Victoria. She compared the species diversity in East African Lakes and reported that the relatively shallow Lake Victoria and the deep rift valley lakes Tanganyika and Malawi, are of worldwide interest for their spectacular flocks of endemic cichlids. She reported that differentiation is greatest in Tanganyika, the oldest lake; Malawi is the most specious (c. 500 species) while Victoria is noted for the loss of about two thirds of its c. 300 cichlid taxa in the last decades. She also provided information concerning:

(a) state of knowledge of the fish fauna,
(b) main threats;
(c) conservation aspects;
(d) economic/management issues;
(e) research needed;
(f) on-going and planned projects.

Ecological and ethological studies have emphasized the importance of trophic radiations and behavioral adaptations for partitioning resources of food and space, thereby permitting coexistence in these very diverse communities in the lakes. However, escalating human populations and increasing demands for food-fish have led to decline in catches of indigenous species in Lake Victoria. Furthermore, in Lake Victoria eutrophication and associated deoxygenation has reduced the volume of fish habitats. Combining conservation of biodiversity and maintaining optimum yields from the fisheries calls for a unified lake basin management for this lake. These trends and the apparent loss of so many endemic species from Lake Victoria stresses the urgent need for intensifying research on biodiversity degradation and its socio-economic implications in Lake Victoria.

4.2. Fish Species diversity and Population abundance

A substantial body of information exists on species diversity of the East African Lakes especially Lake Victoria. Johnson, *et al* (1996) reckon that Lake Victoria harbors more than 300 endemic species of haplochromine cichlid fish. From their study on seismic reflection profiles and piston cores they revealed that the rate of speciation of cichlid fish in this tropical lake has been extremely rapid. Studies by McCune (1996) and Greenwood (1994) provided further information on rapid speciation of the fisheries in Lake Victoria. So spectacular is the extent and rate of evolution and speciation of the fishes of the Great Lakes of East Africa that the terms **"evolutionary avalanche, explosive evolution and explosive speciation"** have been used to describe the phenomena. Furthermore, Fryer and Iles (1972) and Greenwood (1994) suggest that the cichlid fishes provide better and more illuminating examples of evolution and speciation than the traditionally cited Darwin's fishes. There are, for example, more than 800 species of cichlids in the East African Great Lakes, but no more than 14 species of fish in the Galapagos Islands (Ribbink 1988). Reports by Fermon (1996) and Sturmbauer and Meyer (1992) reveal that the fish fauna of Lake Victoria is mainly composed of endemic cichlid species with a high level of morphological diversity, showing that this family of fishes is one of the most remarkable examples of adaptive radiation among vertebrates. However, because of the youth of this "species flocks"(25 000 years old), it is relatively difficult to separate the various species from one another. Kaufman and Ochumba (1993) have also reported

on the evolutionary trends of cichlid species as revealed from their studies using faunal remnants in northern Lake Victoria.

According to Ogari (1992) there are thirteen families of fish in Lake Victoria divided into six cichlid and 15 non-cichlid genera. He reported that there are 51 non-cichlid species and over 350 cichlid species in the lake. The decline and succession of species due to over-fishing over the years was described by Ogari (1992). Originally fishing in Lake Victoria depended on the two tilapiine namely *Oreochromis esculentus*, and *O. variabilis*. Over-fishing the tilapiine created a decline in catches resulting in succession of the dominant non-cichlid species in the landings. Ogutu-Ohwayo (1992) reported that Lakes Victoria and Kyoga formerly had similar fish faunas of high species diversity. About 15 species or species groups occurred regularly among commercial catches and one group, the haplochromine cichlids had more than 300 spp in Lake Victoria. By the 1960s, stocks of the native tilapiines and other large species had been reduced by selective fishing. Therefore, the Nile perch, *Lates niloticus*, and 4 tilapiine spp, Nile tilapia, *O. niloticus, O. leucostictus, Tilapia zilli*, and *T. melanopleura*, were introduced to improve the poor state of fisheries in Lake Victoria.

Miller (1989) and Bruton (1990) reported that the East African lakes are inhabited by cichlid fishes which are characterized by a complex structure of interaction both between and within species, as is typical of mature ecosystems. This has produced species "flocks" that are unique to each lake in species numbers and diversity. According to Greenwood (1994) and following other recent investigations and taxonomic revisions of the species flock of cichlids in Lake Victoria and other African Great Lakes there is clear evidence that the cichlids of Lake Victoria, Edward and Kivu are components of a closely interrelated superflock, phylogenetically distinct from that of Lakes Malawi, Albert and Turkana. This and other related studies show that there are many similarities between the fish faunas and striking examples between-basin parallelism based on morphological, genetic and phylogenetic analyses may be cited; but little attention has been paid to ecological comparisons except for speculative comparisons between lakes due to lack of data. Miller (1989) reported that most of the cichlid species in Lake Victoria are facing extinction as a result of the introduction of an exotic fish species. Ollowo (1992) studied and reported on some surviving native species of Lakes Victoria as compared to other smaller lakes in the region.

Studies conducted by the Haplochromis Ecological Survey Team (HEST) in the Mwanza Gulf, on Lakes Malawi and Victoria from 1978-1990 has provided a data base that may be used to reveal the effects of seasonality and regional variation in species richness in the lake. They compared the seasonality in breeding of cichlid fishes from these lakes and attempted to summarize and identify limnological factors that influence the patterns of breeding. Such comparisons are useful to identify underlying factors that govern the ecological patterns of these fishes. Results from this area reveal that species richness in fish vary from region to region within the lake. For instance, in regions where rocky shores are close together show a higher number of species than region where stations are well isolated. But, some intraspecific morphological variations were also observed in different sites of the Lake.

Odero (1979) reported on fish species, distribution and abundance in Lake Victoria. Other studies have also been reported on fish species diversity in Lake Victoria and its draining rivers. For instance it has been shown that there are at least 14 species of Barbus in the Lake Victoria basin. Their taxonomic status which forms a working key useful for both field and laboratory studies was described by Balirwa (1990). The distribution of fishes along the Sondu-Miriu River of Lake Victoria, Kenya, with special reference to upstream migration, biology and yield was studied by Ochumba and Manyala (1992). They found that out of the 28 species present in the river, the most abundant were *Clarias gariepinus, Schilbe mystus, Synodontis afrofischeri, Oreochromis variabilis, O. leucostictus*, and *Lates niloticus*. *Micropterus salmoides* and *L. niloticus* are a new development in the river fishery introduced respectively from the highland areas and Lake Victoria. The yield in the river has been reduced from 668 t in 1959 to the current 108 t and species available replaced the once abundant *Barbus altianalis* and *Labeo victorianus*. Mwenesi (1994) gave a listing on some non-cichlid fishes in Lake Victoria as *Alestes* spp., *Schilbe mystus*, *Barbus* spp. *Labeo victorianus*, *Synodontis* spp., Mormyrids, *Clarias mossambicus, Bagrus docmac, Protopterus aethiopicus* and *Mastacembolus frenatus*. Some of these are anadromous fishes i.e. they migrate up affluent rivers during the time of floods to spawn. Anadromesis enables the least adapted stages in the life history to go through a transitional riverine habitat before going back to a lacustrine habitat. The top ranking food items of such fishes are

terrestrial and aquatic insects, vegetable matter, detritus, crustaceans, molluscs, fish, plankton and grit. More recent studies on biodiversity of wetlands around Lake Victoria have shown that these ecosystems and the associated rivers house different fish species. For instance in the Nyando River wetlands, recent studies by Okeyo-Owuor and Raburu (1998 unpl. reports) reveal the existence of several fish species; the most common ones being *Protopterus* spp. and *Clarias* spp. and *Xenoclarias* spp. Several riverine and wetland species, though rare, are still found especially during the rainy seasons in Nyando, Nzoia, Kuja and Sondu rivers which drain into the lake.

Maikweki (1992) examined the status of haplochromines in Winam Gulf, Lake Victoria, Kenya and found that more than 230 species of these brightly colored fish are found in the lake and elsewhere. These fish and other small fish, such as tilapia, form the basis of subsistence and some commercial fisheries and their survival is vital to local people. In recent years the population of haplochromines appear to have fallen dramatically as revealed by data from a 1982 survey in most fishing bays such as Kusa, Mbita Point, Kendu Bay, and Dunga in the Gulf. These areas appear to be almost clear of haplochromines, producing only a few and juvenile Nile perch (Maikweki 1992). However, reserved areas around Ndere Island, Mfangano Island, the mouth of River Nyando and the area around Kisumu Municipal Slaughter House, were still rich in Haplochromines, previously believed to have declined (Maikweki 1992).

4.3. Fish Communities and changes in population and diversity

The recent ecological changes caused by a combination of several factors may have resulted from disruptions on the evolutionary trends of indigenous fish species in Lake Victoria. This may have in turn resulted in marked changes in the fish communities and the fisheries that depend on them. While the three proposed methods of conserving the indigenous flocks of cichlid fishes (captive propagation, reducing Nile perch stocks and closure of the haplochromine trawl fishery) all have merit, the changes that are occurring in Lake Victoria appear to be basically irreversible (Bruton 1990). There has been a decline, and in some cases an almost total disappearance, of some of the native fish species of Lake Victoria since the development of the fisheries of these lakes was initiated at the beginning of this century. Ogutu-Ohwayo, (1990) and Witte *et al* (1992) reported that Lake Victoria fish fauna included a large endemic flock of more than 300 haplochromine cichlid species of which about two thirds have disappeared or are threatened with extinction. They describe the decline of the haplochromine species and demonstrate that the rate and sequence of their decline was determined by their relative abundance, adult size and habitat overlap with Nile perch. Many non-haplochromine species declined as well, but in contrast, stocks of the native pelagic cyprinid *R. argentea* and the introduced *O. niloticus* increased. Katunzi (1985) reported that the fisheries for tilapiine cichlids, *Bagrus, Protopterus* and *Clarias* are historical and some might have exceeded the limits of their maximum sustainable yield and that the fisheries for *Haplochromis, Rastrineobola* and *Lates* was promising for both national and international investments. He observed that migratory fisheries of *Labeo, Synodontis, Schilbe, Alestes* and *Barbus* are in danger of total depletion due to improper management, while one species, *Mastercebelus* sp., was considered extinct from the lake's Nyanza gulf. Lowe-McConnell (1992) described the changes in the fish fauna, their ecological effects and the current status of knowledge. She looked at changes in the fish fauna over four decades, from initial ecological work at EAFRO (1949-1953), followed up by analyses of subsequent annual reports and published literature to provide a framework of events of special significance for understanding present conditions in the lake and the action plan for research and management. In a later study on the ecology and behavior of cichlids in the African Great Lakes, Lowe-McConnell (1994) observed that the ancient Lakes Tanganyika, Malawi and Victoria have evolved the most diverse faunas of endemic fishes, mainly cichlids, than any of the world's lakes. However, Lake Victoria has undergone a series of faunal and limnological changes in the past 40 years. Witte *et al* (1992) described the species extinction and concomitant ecological changes in Lake Victoria.

Several reasons have been advanced for the continued decline in fish species richness and abundance, especially the Haplochromine group, in Lake Victoria. Reinthan and Kling (1994) observed that trophic ecology of the lake has changed via alterations in predator-prey, competitive interactions and the removal of certain trophic groups from the aquatic ecosystem at a faster rate compared to other lakes in the temperate regions. They advanced three hypotheses and presented models to explain the observed changes: (1) predation by Nile perch on the native cichlid fish

fauna has altered the food web and caused a trophic cascade, (2) increased nutrient inputs from the catchment or the atmosphere have resulted in the observed eutrophication, and (3) modifications in the stratification and mixing regimes of the lake brought about by climate change have produced the observed limnological changes. However, they concluded that all three hypotheses could be involved in the eutrophication of the lake and are not considered mutually exclusive. Bugenyi (1992) examined the limnology of Lake Victoria and changes in the ecosystem, considering in particular effects on the exploited fish stocks in relation to the transformation of the fisheries because of the success of the introduced fish species - *Lates niloticus* and *Oreochromis niloticus*; He reported that this phenomenon has led to various ecological and physico-chemical changes in the lake's environment. According to studies by Maikweki (1992) in Winam Gulf there was evidence to suggest that overfishing with fine-mesh nets is partly to blame for the disappearance of haplochromine species, and causing an ecological disaster. Other reports by Goldschmidt (1992), implicated the introduction of the Nile perch into Lake Victoria as the cause of the destruction of about 65% of the endemic haplochromine cichlids. They lamented that this represents eradication of approximately two hundred vertebrate species in less than a decade, which may well represent the largest extinction event among vertebrate during this century, resulting into far-reaching changes in the food web currently taking place in the lake. The bottom dwelling detritivores contributed most to the demersal ichthyomass. An analysis of the pelagic community in the sub-littoral area of the Mwanza Gulf revealed that the phytoplanktivores formed 17.7% of the biomass of the total haplochromine community. These studies show how the lake's collapsed ecosystem serve as a negative example of how easily a complex ecosystem can be irreversibly destroyed if no conservation efforts are put in place to reverse or even halt this trend.

The current arthropogenic activities such as overfishing and pollution have also been partly held responsible for the decline of the multispecies fishery and adversely affected the ecosystem of Lake Victoria (Craig 1992). Changes in the water quality, especially its hydrology and chemistry in the lake, were reported by Hecky and Bugenyi (1992). Talling (1966) reported on the annual cycle of stratification and growth in Lake Victoria. Other ecological changes in Lake Victoria have been reported by Marten (1979); Ligtvoet and Witte (1991); Lowe-McConnell (1994); Kaufman (1992); Reinthal and Kling (1994); Ochumba *et al* (1992); Mwebaza-Ndawuli (1994); Ochumba and Kibaara (1989). Gophen *et al* (1995) also reported on some aspects of perturbation in the structure and biodiversity of Lake Victoria ecosystem and observed that the dramatic ecological changes occurred after the introduction of the Nile perch in the 1950s as a result of which an extraordinary spectrum of endemic haplochromine fish suffered massive reductions. Originally, the massive species flock comprised nearly 400 species encompassing a wide trophic spectrum and made up 83% of the lake's total fish biomass. The concurrent system changes in nutrient dynamics may have contributed to the decline/extinction of the haplochromine fishes. Kaufman (1991) described factors underlying ecosystem collapse in Lake Victoria and Seehausen (1994) described the disappearance of cichlids in Lake Victoria as a sad record of declining biodiversity and disappearance of cichlids in Lake Victoria. Other factors thought to be responsible for ecological changes of Lake Victoria are its morphometry and hydrology, such as occasional violent storms in the Nyanza Gulf. This can result in a condition in which nutrient-rich bottom mud is mixed with the sediment-laden runoff water from neighboring marshes and rivers possibly leading to massive fish kills such as that reported by Ochumba (1990).

There are also indications of an increase in phytoplankton, macrophytes, shrimps and benthic organisms. Many of these rapid changes in the lake's ecosystem are probably the effects of the increase of the Nile perch and the disappearance of the haplochromines. The original fish fauna in Lake Victoria included many primary and secondary consumers. Currently, secondary and tertiary consumers dominate. The food web in the sub-littoral and offshore areas of the lake changed considerably due to the stock replacements. Many communities living around Lake Victoria are under intense pressure to meet escalating needs for animal protein. As requirement for fish protein is rising rapidly in relation to increasing human populations, Ribbink *et al* (1985) predicted that these fish communities will be subjected to even greater fishing pressure in the future. According to Ogutu-Ohwayo (1990), *L. niloticus* is thought to have caused the reduction in the stocks of several species. But overfishing and competition between different species also appear to have contributed to this decline. By the time the Nile perch had become well established, stocks of the native tilapiine species had already been reduced by overfishing.

The *Labeo victorianus* fishery had also deteriorated following intensive gillnetting of gravid individuals on breeding migrations (Ogari personal comm.). *L. niloticus* is, however, capable of preying on the species which have been overfished and could have prevented their stocks from recovering from overfishing. *L. niloticus* is also directly responsible for the decline in populations of haplochromine cichlids which were abundant in these lakes before it became established. Bwathondi (1988) gave an account of changes in the fish species composition of the lake during the period 1981-85 with respect to the impact of the introduction of *L. niloticus* in Lake Victoria, Tanzania. He discussed the distribution and nature of the species in the lake with regards to the controversy that exists i.e. the usefulness/hindrance of the species' introduction. Ochumba *et al* (1991), Kaufman *et al* (1992) and Kaufman and Ochumba (1993) reported that the fisheries in Lake Victoria have undergone successive disruptions since the early 1920s. Major contributing factors have been the intensive non selective fisheries, extreme modification of the drainage area, invasion of the introduced species and the progressive change of physical and chemical factors in the aquatic environment. By studying the feeding ecology of the commercially important tilapias in Lake Victoria, Kaufman and Ochumba (1993) found that out of 1698 specimens, *Oreochromis esculentus* was absent, *O. varibilis* was rare, while *O. niloticus, Tilapia zillii* and *O. leucostictus* were abundant.

Amongst the recently introduced fish species in Lake Victoria Ogutu-Ohwayo (1992) reported that stocks of *L. niloticus* started to increase rapidly followed by the Nile tilapia. As these introduced spp flourished, stocks of most of the native spp declined rapidly and some completely disappeared; of all the native spp, only *R. argentea* was still abundant by 1988. Abiotic and biotic factors affecting the diversity of the native fish fauna were also discussed by Ogutu-Ohwayo (1992) in Uganda. In Jinja, Uganda Basasibwaki (1992) reported that the gillnetting and beach seining operations in Napoleon Gulf of Lake Victoria indicated considerable decline in haplochromine abundance and species diversity as compared with the situation in the same gulf twenty years ago. There was differential disappearance among the five trophic groups examined. He observed that since Lake Victoria ecosystem was unstable, it was difficult to predict future trends of the surviving haplochromines in the lake. Other studies in Uganda by Okaronon (1994) found that the fisheries in Lake Victoria are changing rapidly: haplochromids, lungfish (*Protopterus aethiopicus*) and catfishes (*Clarias mossambicus* and *Bagrus docmac*) are disappearing fast from the catches; two introduced species (*Lates niloticus* and *Oreochromis niloticus*), together with the indigenous *Rastrineobola argentea*, are now the only important species.

In Kenya, Asila (1994) reported that changes in the species composition of the fisheries have been influenced by an array of factors, namely the establishment of 2 of the 6 introduced species, changing exploitation patterns of the fishery necessitated by the increase in population, disappearance and re-appearance of some fish species, political and socio-economic development of the riparian states, introduction of more complex fishing gear into the lake, interspecies competition and an insatiable external market. Ogari (1992) observed that the decline and succession of species is due to over-fishing over the years. According to Ogari (1992), originally fishing depended on the two tilapiine species namely *O. esculentus*, and *O. variabilis* but the recent over-fishing of the tilapiine created a decline in catches resulting in succession of the dominant non-cichlid species in the landings. He observed that the management measures applied to improve the fishing in 1950s and early 1960s such as introduction of *L. niloticus* and *O. niloticus* into the Kenyan waters has impacted negatively on the diversity and abundance of the indigenous species as they became established. Recent massive fish mortalities in Lake Victoria have been reported by Ochumba (1992) and Kaufman and Ochumba (1995) and drastic ecological changes due to human perturbation of the lake's ecosystem has been implicated as the cause. Wandera (1992) discussed the possible causes of occasional massive fish death in Lake Victoria.

Studies in Tanzania by Witte *et al* (1992) revealed some vital information on the dynamics of the haplochromine cichlid fauna and ecological changes in the Mwanza Gulf of Lake Victoria. Witte *et al* (1990) also reported on reproductive strategies of zooplanktivorous haplochromine cichlids from Lake Victoria before the Nile perch boom. Further work by Dawes (1986) revealed that Lake Victoria indigenous fish species, especially cichlids, face extinction.

The fisheries of Lake Victoria have undergone substantial changes in recent years owing, in particular, to the rapid proliferation of the introduced *L. niloticus* (Reynolds and Greboval

1988). There has been intense controversy over its impact on the fisheries of the lake, especially with respect to the ecological disruption of endemic species and its possibly adverse socio-economic/advantageous consequences. Studies on the aspects of the evolution of the Nile perch fishery shows the impact of Nile perch to have been both profound and ambiguous. Globally, the Nile perch fishery has been so far an exceedingly positive development from an economic benefit and food resource viewpoint (Reynolds and Greboval 1988).

However, ecological implications of Nile perch in the lake has caused a lot of concern. Presently, *Lates* is the largest predator in Lake Victoria (Bwathondi 1985). The actual predominance of the species and *O. niloticus eduardinus* (*Tilapia nilotica*) in the catch is an indication of vital changes in the constancy of taxonomic assemblages. Ssentongo and Welcomme (1985) speculated that as the prey consisting of phytoplanktivores, zooplanktivores and benthos feeders continue declining, Nile perch will suffer from inadequate food supplies and subsequently have reduced growth and recruitment. Originally *Lates* was piscivorous, its diet reflecting the composition of the native fish community. But recent studies have revealed that its diet is now almost entirely comprised of *Caridina nilotica*, a small microphagous prawn, and juvenile *Lates*. Native fish species, except for the small pelagic *Rastrineobola argenteus*, are very rarely consumed. This change in diet is a result of the shattering impact *L. niloticus* predation has had on the native fishes, which have been virtually wiped out. The original community, which was dominated by several hundred haplochromine species and the catfishes *Clarias mossambicus* and *Bagrus docmac* which preyed upon them, which included two endemic tilapiine cichlids and 38 species of non-cichlids, no longer exists. It has been replaced by a community dominated by *L. niloticus* which now accounts for well over 80% of the fish biomass in the Nyanza Gulf. The only other species regularly encountered are *O. niloticus* and *R. argenteus* (Hughes 1986).

Comparing developments in areas with and without a haplochromine fishery reveals that the impact of *L. niloticus* on the haplochromine stock in order of magnitude is larger than that of other fishes. In most regions the majority of the fishermen have turned to fish on *L. niloticus*, sometimes hampered by the lack of suitable material (Goudswaard and Ligtvoet, 1988). In an *FAO fisheries report* (1987) the impact of *L. niloticus* on the fish ecology in the Kenyan waters is discussed with respect to predation on other fish species and competition for food. Changes in the diet of *Lates* was found to decrease, with respect to the abundance of target prey being the major factor affecting the changes in food organisms. *L. niloticus* has thus had a direct impact on other fish species in the lake (*FAO fisheries report* 1987).

According to Ogutu-Ohwayo and Hecky, (1991) *L. niloticus* in the lake has virtually eliminated a number of endemic species resulting into the loss of genetic diversity accompanied by a loss of trophic diversity; the transformation of the fish community coincided with profound eutrophication (algal blooms, fish kills, hypolimnetic anoxia) which might be related to alterations of the lake's food-web structure. Riedmiller (1994) observed that introduction of the Nile perch into Lake Victoria has dramatically altered the fishery in that lake and contributed to the decline of the fishery for indigenous tilapias. Hoza (1990) analyzed the evolution of fisheries systems of Lake Victoria between 1979-1989, taking into consideration the major changes which have occurred in the fisheries before and after the introduction of Nile perch and reported significant ecological and species diversity alterations.

However, according to Getabu (1988), the major fisheries started to decline long before the introduction of the Nile perch (*L. niloticus*), therefore it is questionable whether this predatory species is the sole cause of decline in the stocks of tilapia and anadromous fish. Acere (1988) argued that the introduction of *L. niloticus* was conducted mainly to increase fish populations for the ever increasing human population following the collapse of the endemic tilapia fisheries. He reviewed the events which have taken place in the lake regarding its fisheries in order to understand better the controversy which currently exists. He observed that the decline of the haplochromines of the lake is most probably due to overfishing and to some extent as a result of the piscivorous habits of adult Nile perch. Reynolds and Ssali *et al.* (1990) also argue that the decline of the haplochromines is as a result of predation pressure in combination with fishing mortality and environmental change. They go on to argue that although the Nile perch has been highly valued as a "producer of food and wealth", this has resulted in massive ecological upheaval, which has made it difficult to evaluate the costs and benefits involved. However, Ogari (1988) observed that prior to the introduction of *L. niloticus*, a balance between predators and prey

species had evolved in Lake Victoria. Adaptations by both predators and prey had ensured that extermination of a species would not occur as a result of predation. In Lake Victoria, as in other lakes where this species has been introduced, many endemic prey-species have been almost eliminated and the *L. niloticus* population is now largely cannibalistic (Ogari 1988). The view of Ogari (1988) is supported by other authors such as Reynolds and Greboval (1988), Moreau, *et al* (1993), Achieng' (1990), Mkumbo and Ligtvoet (1992) and Asila (1994). Okaronon (1994) conducted a bottom trawl survey in Uganda sector of Lake Victoria during the period May 1993 through May 1995 to establish the current composition, distribution and abundance of the fish stocks. Fourteen fish taxa (excluding the Haplochromis) were recorded, with *L. niloticus* making up the bulk of the fish retained. Turner (1994) observed that despite the vulnerability of individual species, Lake Malawi's haplochromine cichlid communities have been shown to be capable of sustaining high yields at high levels of exploitation, suggesting that the replacement of the haplochromine cichlids by Nile Perch in Lake Victoria is unlikely to have been a consequence of fishing.

4.4. Other vertebrates

Lake Victoria, especially its wetland ecosystems, is rich in vertebrate species other than fish, most of which are not yet well studied. An important factor is the trophic interactions in the changing ecosystems in Lake Victoria, especially after the introduction of exotic species such as *L. nilotus* and in relation to higher vertebrate taxa such as the associated birds species. According to Goldschmidt *et al* (1993), the principle of cascading trophic interactions has been documented in Lake Victoria, after the introduction of this top predator. There is some evidence that the diets of the some aquatic invertebrates and birds in Lake Victoria has changed with time following the introduction of new fish species and the decline in indigenous species (Goudswaard and Wanink 1994). For instance, Goudswaard and Wanink, (1994) reported that the introduction of the Nile perch into Lake Victoria, has also resulted in changes in the diet of pied kingfishers (*Ceryle rudis*). These birds fed mainly on haplochromines. Only the young nestlings depended on *dagaa* as primary food. The current diet of adult birds clearly reflects the changes which have occurred in the fish community. Pellet analysis reveals a shift towards a diet composed of almost 100% *dagaa*. The change in prey species composition has increased the number of fish a kingfisher needs to catch daily in order to meet its energetic demands; the mean size of haplochromines is larger than that of *dagaa*, the mean size of *dagaa* has decreased since the increase in Nile perch; the weight of *dagaa* is lower than that of haplochromines of equal size; and mainly juvenile *dagaa* and adults in poor condition are accessible to kingfishers. It would be of great interest to investigate the changes that may have occurred in the diets of other fish eating birds, mammals and reptiles within the lake possibly as a result of ecological changes caused by the Nile perch and other factors.

4.5. Invertebrates

Some work has been reported on the diversity and abundance of invertebrate communities in Lake Victoria. For example, in Jinja, Uganda, Mbahinzireki (1994) studied the benthic communities of northern Lake Victoria and reported on their distribution and abundance in relation to the ecological changes in Lake Victoria. The results suggest that the density of most zoobenthos has increased since the pre-perch era, despite the absence of comparative data. Higher densities were recorded in the dipteran larvae, oligochaetes, *Caridina nilotica*, molluscs and other insect nymphs, most of which contribute significantly to the diet of the lake's ichthyofauna. Type of sediment and physico-chemical factors seem to influence the production and distribution of these organisms in the lake. According to Mwembaza-Ndawuli (1994) the pelagic ecosystem of the northern Lake Victoria is characterized by crustacean zooplankton in which the component taxa are Copepoda, Cladocera and Decapoda. Non-crustaceans are represented by the semi-benthonic chaoborid and chironomid larvae which constitute relatively small proportions of the total zooplankton. Macrozooplanktonsuch as fish larvae are rare. Copepods and Cladocerans exhibit a cosmopolitan distribution while the decapod prawn, *Caridina nilotica* Roux and the dipteran larvae are not as common in the shallow inshore areas as in the offshore waters. Of the copepods, the cyclopoid copepods are by far the most abundant zooplankton constituting over 60% of the total zooplankton, while diaptomids, cladocerans, prawns and the dipteran larvae contribute relatively small proportions. They compared the present abundance data with past records and reported remarkable structural changes in the zooplankton community which may relate to corresponding changes in some water characteristics and food-web structure in the lake. Mugidde (1994) also reported the changes in phytoplankton primary productivity and biomass

in Lake Victoria, Uganda. Other reports have been given on Crustaceans in Lake Victoria, Uganda by Kateyo (1992). He recorded four sub-classes, four orders, more that ten families and 20 general in the lake.

Other reports are available on the phytoplankton and zooplankton communities as they relate to the dynamics of food chains of fish communities in the Lake. Ambleside (1987) reported on the phytoplankton communities in the lake. Kudoja *et al* (1992) studied the vertical distribution of nine *Haplochromis* species (family cichlidae) in relation to their feeding habits as well as the physico-chemical parameters of Mwanza Gulf of Lake Victoria. They reported that *Haplochromis kribensis*, H. orange head, *H. heusinkveldi* and H. yellow head were found to inhabit the surface waters. Others such as *H. nigrofasciatus* and *H.* curved head were found to inhabit bottom waters. No conclusion was reached as regards the distribution of *H. argens, H. lengthistripe* and *H. aricutus* due to their insignificance in the catch composition. The main phytoplankton species found were *Anabaena* spp. and *Melosira* spp. The population of *Anabaena* spp. decreased with increasing depth while *in Melosira* spp. it was the reverse. Cyclops and Diatomus larva were the main zooplankton species found. Cyclops population increased with depth and Diatomus larvae decreased with increase in depth. Analysis of the gut contents indicated a correlation between the distribution of *H. kribensis* and *H. nigrofasciatus* with *Melosira* spp. The studies also showed that measurable physico-chemical parameters were relatively constant over the depth range of interest (i.e.1-14m) but never seemed to directly affect the distribution of the Haplochromis. Kasindye (1992) also reported on the composition, abundance and vertical distribution of phytoplankton in Mwanza Gulf of Lake Victoria, Tanzania. He found that the percentage composition varied with depth, and generally abundance decreased with depth. He used physical-chemical factors to explain these distribution patterns. At Murchison Bay, Lake Victoria, Uganda, studies have revealed the presence of some 19 genera comprising of 51 species in the diatom communities. It was also observed that the frequent fish kills and blockage of the pumping station was associated with periods of algal abundance. Mugidde (1994) gave a detailed account of the changes in the phytoplankton primary production and biomass in the Ugandan portion of Lake Victoria. Thus, adequate knowledge of the algae is valuable to biodiversity studies, water treatment works and fisheries management. There are also indications of an increase in phytoplankton, macrophytes, shrimps and benthic organisms. Many of these rapid changes in the lake's ecosystem are probably the effects of the increase of the Nile perch and the disappearance of the haplochromines.

4.6. Plants and Micro-organisms

Some reports are available in the literature on the species diversity of flora and micro-organisms in Lake Victoria. Gichuki and Odhiambo (1994) reported results on ecological study of macrophytes and their role in the economy of the lower Sondu-Miriu river of Lake Victoria. A total of 34 species of aquatic macrophytes were identified and grouped as emergent, floating leaved, free floating and submerged. The major community type identified were dominated by *Cladium jamacanse* (Crantz) Kurk., *Cyperus papyrus* (L.) and *Cyperus latifolius* (Poir). Although the study found an over dependence on macrophytes by the local community for a variety of uses, the ecosystem is also valuable in providing fish as the only source of protein in this semi-arid region. It was also observed that these ecosystems serve as sanctuary and breeding sites for birds which inhabit the swamp. The swamp provides the only source of green pasture in the dry season for both wild and domestic animals.

In recent years the invasion of water hyacinth (*Eichhornia crassipes*) into Lake Victoria has contributed significantly to changes in the aquatic ecology of the lake. Twongo (1992) reported on the spread of water hyacinth on lakes Victoria and Kyoga and some implications for aquatic biodiversity and fisheries. Although this aquatic weed has been established in Lake Victoria for less than ten years now, all riparian states have recorded the presence of the weed and extensive hyacinth mats are already a common feature along suitable lake shores in Kenya, Uganda and Tanzania. The implications of water hyacinth infestation on the lake for aquatic biodiversity and fisheries were discussed by Twongo (1992) on the basis of some preliminary observations in Uganda. Some more work on the effects of the weed on the biodiversity and fishing communities in Lake Victoria is still in progress (Kilonzo 1996, M. Onyango 1996 Unpbl., Okallo 1998 unpubl., S.O. Munga, 1998, unpubl).

4.7. Ecosystems diversity

The ecosystems around Lake Victoria are quite diverse and form different ecological niches or

habitats for the lake's rich species diversity. The riverine and associated wetland ecosystem is characterized by a number of rivers that empty their waters into the lake. Research on these ecosystems are lacking, except for some limited knowledge of the fisheries resources which they host. Recent studies by Chapman *et al* (1996) in Uganda revealed that wetland ecosystems in Lake Victoria act as a refuge for endangered fishes from *L. niloticus*, and other predators, by providing both structural and low-oxygen refuge for prey species tolerant of the conditions that prevail in these habitats. They examined the potential of wetlands as a refuge for fishes in Lake Nabugabo, Uganda, where increased numbers of an introduced predator, *L. niloticus*, coincided with the decline or disappearance of many indigenous species in the main lake. Chapman *et al* (1996) reported more indigenous fish species in the wetland ecosystem than in the open lake. Three of these species were found only beyond the margins of the lake in the tributaries and lagoons within extensive wetlands. One of the three endemic haplochromine cichlids which were abundant offshore in 1962 has to date disappeared and the others are now largely confined to inshore areas. Other species that were present in both wetlands and open waters of the lake in 1962 (e.g., the lungfish *Protopterus aethiopicus*) are now found primarily in wetlands (Chapman *et al* 1996) .

Two species, the characid, *Brycinus jacksonii* and the cyprinid, *R. argentea*, are still abundant in the open waters. This study highlights the need for quantitative surveys to identify wetland refuge in the Lake Victoria Basin and show that some species thought to have disappeared in the mass extinction of fishes in Lake Victoria may still survive in refuge. They suggested that some fish populations could recover under effective ecosystem management.

Although this review is not strictly concerned with the geological evolution on Lake Victoria ecosystem, it is worth mentioning that the indigenous species diversity and fish communities in the Lake are closely related to its evolutionary history. The possible evolutionary history of the lake's fauna, from Miocene times onwards are the consequences of that history on the phylogenetic relationships of its ichthyofauna. In all respects, the lack of an adequate fossil record for the Lake Victoria basin and its fauna hampers the formulation of adequate hypotheses on its ecological evolution. In discussing the speciation and fluctuating environments with reference to ancient East African lakes, Coulter (1994) reviewed information on surface level fluctuations in Lake Victoria and other lakes and discussed their deepwater habitats, evolution and habitat type, and rates of speciation. He examined the relationships between fluctuations in the lake environments and modes of their evolution.

4.8. Biodiversity Conservation in Lake Victoria

At the moment the *biological integrity* of the Lake Victoria and its biodiversity are in a precarious condition. Biological integrity was defined by Angmeier and Karr (1994) as being "a system's wholeness, including the presence of all appropriate elements and occurrences of all processes at an appropriate rates". This definition is based on ecological principles and may also be referred to as the Index of Biotic Integrity (IBI). According to Karr (1991), the IBI is based on an array of indicators combined into one or more simple indices and may be used to detect degradation, identify its cause and determine its improvement results from management action. Angmeier and Karr (1994) compared the utility and merits of biological diversity versus biological integrity and preferred the use of the latter for the purposes of conservation and management. Development of IBI for tropical ecosystems such as that of the Lake Victoria faces the constraint of lack of baseline information from which to construct indices. However, there is sufficient evidence that the situation in Lake Victoria needs urgent conservation and management intervention. Fortunately, the situation is not yet out of hand, although some species in the lake have been classified as extinct or rare in the 1988 IUCN Red Book of endangered species.

Some authors have reported on the need for conservation of fisheries resources and the general biodiversity in Lake Victoria. Ex-situ research in this direction has been in progress in several institutions. Seehausen, and Frans (1995) examined the current situation, the extinction, survival and the need for conservation of cichlids in Southern Lake Victoria. Seehausen (1995) reported on decline of the cichlid species and rescue efforts in Southern Lake Victoria. Chapman *et al* (1995) reported that, of the species flock of haplochromine cichlids, which are now faced by mass extinction, some exhibited relatively high tolerance to hypoxia. This phenomenon suggest that these species potentially could use low-oxygen refuge to escape Nile perch predation; thus ensuring their suitability for conservation. In designing a conservation plan for

lake species flocks it is critical to take into account the difficulty of defining phylogenetic units of preservation in rapidly diverging endemics. It is essential to consider the metapopulation structure likely for many endemics and the role of this structure in maintaining locally high diversity (Chapman *et al*,1995). The dynamic nature of metapopulation extinctions and reinvasions cautions us that today's hotspots of diversity may not be "permanent" features of a lake's landscape. A historical or paleoecological evaluation of diversity changes, extinctions, and invasions (a ***dynamic biodiversity assessment***) should be undertaken on presumptive hotspots (particularly those in undisturbed areas) prior to establishing a series of reserves based on species complementarily. Studies in Lake Victoria by Kaufman *et al* (1992) have revealed persistent native faunal elements, including species associations peculiar to deep gulf, sand, open water, mesolimnetic and peripheral pond environments, in addition to the already known littoral rock and papyrus fringe refuge. These circumstances could be valuable for conservation of fisheries resources in the lake. Bruton (1990) observed that most African Great Lakes including Lake Victoria, are considered to be dynamically fragile ecosystems that are relatively resistant to minor changes within which they have co-evolved but vulnerable to major perturbations such as overfishing, the introduction of alien species and pollution. He proposed methods of conserving the indigenous flocks of cichlid fishes (captive propagation, reducing Nile perch stocks and closure of the haplochromine trawl fishery), but observed that the changes that are occurring in Lake Victoria are irreversible.

Bruton (1990, & 1995) reviewed the conservation status and factors threatening fishes worldwide and suggested the incorporation of information on threatened fishes into international conservation programmes. He stressed that further research on minimum viable populations, genetics, and the factors that cause fishes to become vulnerable to extinction, is urgently required. Although captive breeding programs have played a useful role in the conservation of endangered terrestrial organisms (Schleser and Loiselle 1994), and similar practice is being promoted for the conservation of terrestrial organisms in Kenya, little work is underway on Lake Victoria's endangered species. Other workers have reported on the need to conserve the fish resources in Lake Victoria; including reports by Calamari *et al* (1992), Bartley (1993), Ogutu-Ohwayo (1992), Cohen (1994), and Schneider and Van Dijk (1994) all of whom suggested environmental management measures for preventing further deterioration of Lake Victoria Basin.

Marten (1979) examined the fishing methods in Lake Victoria and recommended that the best strategy for maximizing the total tonnage yield is to fish optimally for the herbivorous genus Tilapia. This means using only the larger gillnets appropriate for Tilapia, as well as hooks. The hooks capture large predators such as *Bagrus, Clarias,* and *Protopterus,* an abundant resource in themselves, and simultaneously appear to increase Tilapia yields indirectly by reducing losses of Tilapia to predators. Lowe-McConnell (1992) recommended that planning for the lake's future should be a two-pronged approach, aimed at conservation of the remaining indigenous species and managing the fisheries to maintain the greatly increased fish yields with emphasis on tilapia and changes to the non-cichlid fish fauna. In a recent workshop held in Rongo, Kenya, Onyango (1998) reviewed the role of the Fisheries Department in Kenya in the conservation fisheries and emphasized the need to enforce closed seasons, the use of appropriate fish gears and community education for enhancing conservation efforts in the lake.

5. SOCIO-ECONOMIC RESEARCH AND BIODIVERSITY

5.1. Socio-economics of fisheries species diversity

Previous research work on Lake Victoria has mainly focused on the bio-physical aspects. During the last three decades or so and following the ecological changes observed by biologists in the lake the research on socio-economics is gaining fast pace. The fisheries of Lake Victoria have undergone substantial changes in recent years owing, in particular, to the rapid proliferation of the introduced Nile perch (Reynolds and Greboval, 1988). There has been intense controversy over the impact of this introduced predator species on the fisheries of Lake Victoria with respect to the ecological disruption of endemic species and its possibly adverse/advantageous socio-economic consequences. Geheb and Binns, (1997) examined the relationships between fishing and farming in providing household income and nutritional security among Luo communities on the shores of the Kenyan sector of Lake Victoria. They reported that in recent years the resources of Lake Victoria are under severe pressure due to a variety of economic and ecological factors associated with

over-fishing and a significant decline in fish species. This report has prompted several socio-economic studies in the region, one of which is the current attempt by Tegmeier (1998 in progress, personal comm.) to analyze and understand the coping strategies of the fisher farmers and farmer fishers in the Winam Gulf of Lake Victoria. According to O'Riordan (1996) a major shift is needed in the management of Lake Victoria resources. He argued that management of Lake Victoria's fishery resources is in need of reform to prevent a collapse in fisheries related, local economies and environmental degradation. He also examined the utilization of naturally occurring renewable resources in relation to the exploitation of fishery resources in Lake Victoria. O'Riordan (1996) studied and reported on some of the issues facing the riparian communities including increasing pollution in the lake; the changing nature of the fishery especially with regard to predation by the Nile perch; the intrusion of water hyacinth; new initiatives in aquaculture in the area; current fisheries sector policy; management, and interventions and fish processing and marketing in West Kenya.

Although there is much concern about the environmental degradation of Lake Victoria, there is often only partial appreciation of the very important role fisheries economics as a discipline can play in the unraveling of the internal workings of fishery systems. It should be noted that this role extends to the formulation of management, development and research strategies, the assessment of the impact of intervention measures, and so on. The complexity and diversity of the inter-related variables that dominantly control the behavior of fishery systems, mean that the knowledge and understanding of the system structure remains incomplete if it omits a subset of important social-economic variables. Some socio-economic studies have shown some unique behavioral characteristics amongst the fishing communities living around Lake Victoria. For instance, Kibwika (1991) studied the fishing behavior and problems of the fishing communities in Ssese Island, Lake Victoria, Uganda and found that unlike other mainland fishing communities, the island communities have unique problems which can not be categorized with others when looking for solutions. In Kenya, Kongere (1979) reported on the production and socio-economic aspects of the fisheries in Lake Victoria. Mokua (1992) reported on the socio-economic factors influencing the choice of fishing gears among fishermen in Lake Victoria.

5.2. Socio-economics of Nile perch fisheries and recent changes

One factor that has caused great concern on the fisheries and socio-economic revolution amongst the Lake Victoria communities is the introduction and proliferation of the Nile perch into the lake (Kuthongania *et al* 1992). Karuhanga (1990) used data from Lake Victoria to develop econometric models and gave a listing of some social-economic variables to highlight their importance in explaining fishery input-output quantity, quality and system variability. The study focuses on variables other than direct fishery inputs and ecological factors in explaining fluctuations in catches. One major factor considered in this study is the introduction of *L. niloticus* and its rapid proliferation whose impact has been plagued by intense controversies, especially with respect to the ecological disruption of endemic species and its possibly adverse socio-economic consequences. Oguto-Ohwayo (1989) examined the purpose, cost and benefits of fish introductions in the Lake and reported that both predation and species competition have resulted in the decline of native species; an issue which has generated conflicting opinions on fish introductions especially in relation to conservation needs of biodiversity and production of adequate protein foods for the riparian communities. The present studies on the socio-economic aspects of the evolution of the Nile perch fishery show that its impact is both profound and ambiguous. Globally, the Nile perch fishery has been so far an exceedingly positive development from an economic benefit and food resource viewpoint. On the other hand, some serious issues warrant careful consideration and further analysis. These relate to the distribution of benefits, especially with respect to the relative role of artisanal and larger-scale fishery operations, and to the fundamental question of sustainability. Under proper management, the fisheries of Lake Victoria, and the Nile perch fishery in particular, could continue to provide high yields and substantial benefits for the riparian communities concerned in Kenya, Tanzania and Uganda.

In their report on people-environment relationships Geheb and Binns (1995) explored the changing nature of the small-scale fishery by taking a historical perspective and examining the pressures facing small-scale fishing activity in Lake Victoria, Kenya. They found that some 85% of Kenya's fish supply comes from Lake Victoria, most of which is landed by small-scale fishermen. By examining the fishing activity in the pre-colonial, colonial and post-colonial periods, they showed

how the once tightly controlled access to fishing with careful management of resources by the indigenous Luo, has been transformed into a 'free for all' resulting in declining catches, increasing commercialization and absentee ownership of fishing boats. These changes have been mostly the consequences of commercial fishing involving the Nile perch. Geheb and Binns (1995) argued that the future sustainability of fishing activity in Lake Victoria will ultimately depend on greater control over access, and possibly the reintroduction of communal fishing grounds and resource management such as existed in precolonial times. In another study Geheb and Binns (1997) examined the issues of "Fishing Farmers" or "Farming Fishermen" in relation the quest for household income and nutritional security on the Kenyan shores of Lake Victoria. Geheb (1996) also reported on fisheries management, options and dynamics in Kenya's Lake Victoria. Adhiambo (1991) examined the socio-economic conditions of the artisanal fish traders involved in the fisheries in the Kenyan sector of Lake Victoria, and described various fish marketing systems used, the role of the middleman and the problems facing the fishing industry and fish trade.

In Kenya Abila and Jansen (1997) and Jansen (1997) reported on some socio-economic aspects of fish trade, at the local and export markets and the effects of trade and aid in the Lake Victoria Fisheries. They observed that the demand for Nile perch in export market has posed the greatest challenge to the conservation of fisheries in the last decade. The fish-meal industry, which demands the use of *R. argentea* (*dagaa* - omena), continues to raise the possibility for even a greater threat to the sustainable exploitation and the conservation of biodiversity in Lake Victoria (Abila and Jansen, 1997). *Dagaa* also forms part of the food chain for the Nile perch. As most Nile perch goes for export and *dagaa* for fish- meal, there is increased effort to catch juvenile fish for the local market which in some beaches constitute nearly 10-35% of the overall landing.

Studies by Jansen (1997) reveal that the export fisheries affect the traditional fisheries and different groups of people who depend on them at different levels i.e. individual, household, community, national and international levels. He reports that there has been dramatic change in fisheries since the introduction of the Nile perch. For instance, during the pre-perch periods, most canoes and fishing gears were owner - operated. Today there are more sophisticated fisheries involving stronger, more expensive gill-nets and absentee fishermen with strong management and large capital investment in the Lake. The traditional fishmongers, the majority of which are women, and their close relations with fishermen is now being severed, as the fishermen are now contracted to deliver to the processing agents with better prices. This phenomenon has also affected the consumers, as evidenced by the present concerns about the food security along the lake shore and with consideration of the present attempts to export the Tilapia (Greboval 1989,1990). Jansen reported that at present the price of whole fish is even beyond the reach of middle class people and the remains of the filleted Nile perch skeleton is considered to be "food for poor people". The export oriented fishery is also a threat with regard to employment for millions of poor people in East Africa and yet there is continued interest amongst the international donor community to support such activities and build up the export oriented fish trade from the lake. Thus, in Kenya, there is already much concern on the current over-exploitation trends of the lake's fishery resources amongst the local communities, fish processors and the government as more and more juveniles which cannot be filleted are landed (Abila and Jansen 1997). These observations lead to the conclusion on the need to control the type of fisheries and expansion of the fish processing and export industry to ensure food security and sustainable exploitation of the fisheries. In recent socio-economic studies Yongo (1998) reported on the impact of changing fish species on nutrition and health of lakeside communities while Gutwa (1998) reported on the marketing of fish and fish by-products and their impact on Lake Victoria lakeside communities. Abila (1998) reviewed the socio-economics of Lake Victoria fisheries in relation to the Lake Victoria Environmental Management Program (LVEMP).

Some socio-economic changes in Lake Victoria have been reported especially in relation to commercial Nile perch fisheries in Tanzania. Katunzi (1990) observed that the lake is a vast fisheries resource and therefore attracts the riparian states to explore the possible ways of identifying the optimal use of its resources. His paper analyses the research and development activities along the Tanzanian side of Lake Victoria and summarizes the major programmes and results. In addition he made an evaluation of the socio-economic effects of these activities and concludes with future recommendations. Mkisi (1991) conducted socio-economic surveys in the Mwanza region on fishermen, processors, traders and consumers with

special emphasis on living conditions, division of ownership, characteristics of fishing units, fishing operations, costs and earnings, and income generation From their research, conducted mostly in Tanzania, Wilson and his colleagues from PLEA have given a series of reports discussing several socio-economic issues related to Lake Victoria fisheries. Such include:

- An analysis of labor remuneration in the Lake Victoria fishing industry" (Wilson 1998);
- Preliminary findings on the implications for fisheries management of the changing situation amongst the fishing communities" (Wilson and Medard 1997);
- Changing economic problems for women in the Nile perch fishing communities" (Medard and Wilson 1996);
- Socio-economic impacts of the introduced species" (Harris, *et al* 1995);
- Potentials for co-management of the Nile perch fishery in Lake Victoria";
- The implications for crew members of the changing structure of the Lake Victoria fishing industry in Tanzania", (Wilson 1995)";
- Preliminary findings on fisher's attitudes towards management on Lake Victoria", (Wilson 1993a);"Focus groups with women in Lake Victoria fishing communities with particular concern on research on issues concerning health and gender in Africa", (Wilson 1993b).

5.3. Socio-economic impacts on other biodiversity

Studies around lake Victoria show that the biodiversity other than fisheries is changing fast and this could be related to fisheries behavior in the lake.

For example, socio-economic studies have been conducted in relation to post harvest losses in fish, fuel, food and forests in Uganda by Ssali *et al* (1992). They reported that the long term socio-economic cost of wastage in the post harvest sector of fisheries involve more than the loss of income and nutritional benefits to fisherfolk communities and their dependent consumer populations. They observed that established methods of fish processing also place enormous pressure on valuable and often scarce timber stocks. These changes draw future research attention to such underlying factors as the "Nile perch effect"; shifting channels of product distribution and marketing, the consequences of prolonged periods of deteriorating national infrastructure and the coping strategies of the communities living along the lake. They also reported on experiences and attempts to ameliorate fish and forest product losses through use of improved traditional processing technology on the one hand and more industrial, capital intensive handling and distribution methods on the other. Ssali *et al* (1992) identified future prospects for solving the array of socio-economic and environmental problems and challenges posed by the "post-harvest loss complex". Reynolds and Ssali (1990) examined the current industrial development in fish processing and marketing for both domestic and export and found that, apart from the major engagement in the Nile perch, there is increasing interest in processing and marketing of tilapia and the small pelagic *Rastrineobola* spp. as well. They presented the socio-economic implications and gave some future directions of the lake fisheries.

This review reveals that many gaps still exist on research regarding the biodiversity related socio-economic problems in the Lake Victoria and its environs. Some of these gaps are identified in this report and recommendations made for further research to help tackle the current environmental problems facing the region.

6. INSTITUTIONS WORKING ON LAKE VICTORIA FISHERIES

In recent times a number of national, international and non governmental institutions have turned their attention into conducting research and conservation on Lake Victoria. In Kenya the following governmental institutions continue to conduct research on different aspects of Lake Victoria some of which are only remotely related to biodiversity and socio-economic issues of the lake's fisheries resources.

6.1. Governmental institutions

6.1.1. Kenya Marine Fisheries Research Institute (KMFRI):

KMFRI has become the key player in Lake Victoria in Kenya research especially targeting fisheries sub-sector. With its station and staff based on the shores of Lake Victoria, KMFRI coordinates and conducts research on fisheries biology, mortalities, stock assessment, aspects of aquatic macro- and micro-fauna and flora as well as some aspects of water quality, pollution and biodiversity degradation. KMFRI also works in collaboration with a number

of international research or donor organizations. Biodiversity and socio-economic research work in KMFRI is at an early stage but some valuable preliminary data has been generated, especially on changes of fisheries diversity as related to species introduction, over fishing and pollution. KMFRI continues to conduct some magnificent work on the socio-economics of Lake Victoria, some of which were presented at the recent seminar on biodiversity and socio-economics held at Rongo, Kenya (27 July-5 August 1998). There is need to focus this work on the changing status the lake's biodiversity. Of particular interest in this review is the KMFRI's work on stock assessment being supported by EEC and the biodiversity and related research supported by the GEF/World Bank LVEMP.

6.1.2. Kenya Medical Research Institute (KEMRI)

KEMRI's station based in Kisumu is mainly concerned with water related diseases in Lake Victoria. Although KEMRI has not targeted its programmes to fisheries biodiversity, it is of interest that some efforts are being placed on changes of biodiversity in disease vectors, their prevalence and disease epidermology as they affect the health and activities of communities around the lake. Data on these aspects will be of great value if synchronized with the socio-economic studies and biodiversity in the lake.

6.1.3. Lake Basin Development Authority (LBDA)

Although much of the data from this organization is rarely published, the work that the authority continues to do in relation to water quality, fisheries and water related diseases in the Lake Basin region can not be ignored. The authority has particularly compiled a lot of row data on water quality and aquaculture that if analyzed will provide an insight into the management of Lake Victoria fisheries.

Other activities of the Authorities that should be examined in relation to their effect on Lake Victoria biodiversity and socio-economic implications include agriculture/horticulture (especially targeting the use of reclaimed Yala Swamp), promotion of brick manufacture, promotion of rainfed rice and aquaculture.

6.1.4. Kenya Agricultural Research Institute (KARI)

KARI plays two important roles in the Lake Victoria region. Firstly, through its research stations, near the lake shore it conducts research on the promotion of sound agricultural practices that would improve farming and agro-industrial activities in the region and the country in general. A number of these activities appear to be in direct conflict with Lake Victoria biodiversity conservation efforts. For instance KARI conducts research on sugar and cotton industries, which remain a major source of pollution and deforestation in the lake's drainage basin with adverse socio-economic and ecological implications. Conservation of the lake biodiversity, especially fisheries, will require that techniques developed by KARI are environmentally friendly. Secondly, KARI has the mandate for research and control of the dreaded aquatic weed, water hyacinth, which has heavily invaded the Winam Gulf hindering fisheries, lake transport and fast changing the lakes ecosystem and biodiversity. The methods being evaluated by KARI for the control of the weed may have numerous implications on the lake's biodiversity and its associated socio-economics. There is evidence that KARI will involve community participation in the control of this weed which deserves a thorough and independent research on socio-economic factors that would support or invalidate such approaches. There is considerable need to focus more research on the effect of agricultural activities on the environment of Lake Victoria and its drainage basins and rivers.

6.1.5. The National Universities

Kenya has four national universities. Although considerable scientific publications exists from individual work done by university scientists, this review considers them not as part of the university's or institutional efforts towards conservation of the lake's biodiversity. Furthermore, past work at the universities are mainly in the form of student thesis outputs, with limited follow up and continuity. In recent times some Kenyan universities have started institutional research on Lake Victoria especially fisheries. Considerable data is available on work done by scientists from Nairobi University, Department of Zoology. In Moi University, research work is in progress at the Department of Fisheries and School of Environmental Studies. In addition to its contributions in capacity building and research in environmental issues of the lake, Moi University has established a research presence on the shores of Lake Victoria, through its Homa Hills Environmental Research Station, where a full team of researchers and postgraduate scholars conduct research on various aspects of environmental and

socio-economic issues. Of particular interest in this program is that this would be one of the rare occasions when university research seeks to involve community in environmental research and conservation. A typical example is the Nyando wetland Conservation Program (NWP) being conducted by the School of Environmental Studies in collaboration with the Kenya Wild Life Service, Lake Basin Development Authority, OSIENALA and the Nyando Wetland Community. Based on this successful pilot project the School's Research Station at Homa Hills will play a key role towards research and conservation of Lake Victoria biodiversity with a strong socio-economic base. According to a report by Okoth (1996), Maseno University College is also establishing a strong base for studies on Lake Victoria, through its recently established Center for the Study of Lake Victoria and its Environs (CSOLVE).

6.1.6. National Museums of Kenya

This has become a major national and regional research facility in biodiversity. With its major biodiversity activities based in Nairobi, the NMK is making good strides towards biodiversity studies in Lake Victoria. The institute is a regional repository of biological specimens in the region both as materials for conservation/preservation, taxonomy and scientific research. Additionally, the NMK collaborates with other national and international institutions in biodiversity research. Biodiversity research on Lake Victoria at the NMK is still at its infant stage and mostly emphasizing generation of basic scientific data especially on species and genetic diversity for fish and related fauna. At the floral level the NMK has participated on collection, identification and preservation of different indigenous flora in Kenya including aquatic and terrestrial plant species in the lake region. Such studies also have some socio-economic interests which the NMK is yet to address. In terms of Lake Victoria fisheries, the NMK has little scientific input except for the current preliminary thesis study on genetic diversity of tilapia in species.

6.1.7. Kenya Wildlife Service

Kenya Wildlife Service is a governmental parastatal with the mandate to conserve the country's wildlife resources including those within the Lake Victoria and its basin. KWS has currently established a biodiversity program for western Kenya. KWS collaborates in and supports programmes on the biodiversity rich wetlands. Other area around the lake where KWS is active is the Ruma National Park, the Ndere Island Natural Reserve, the Kakamega Forest, the Got Ramogi Sacred Forest Project and other areas of ornithological interest. KWS has also supported several biodiversity conservation initiatives in and around Lake Victoria. Of particular interest to this review is the Nyando Wetland Conservation Program, a community based research and conservation program in Nyando River Wetland area. In this project KWS, through its biodiversity and partnership offices in western Kenya, are part of a team conducting community awareness creation, research and demonstration of conservation techniques at the grassroot levels in Nyando District. KWS also has the mandate to control the human-wildlife conflicts in areas outside official gazetted parks. For wetlands in this category, KWS offers advise and protection, especially to the farming communities by controlling the marauding hippos through scaring them back into their wetland habitats. The KWS and indeed the Kenya Government values the lake and its rich biodiversity and places every effort in their conservation. Even with these efforts KWS does not seem to be directly involved with fisheries resources in the lake as much as it does on terrestrial species. Furthermore, there is still no effort to conduct socio-economic research in this area.

6.1.8. Lake Victoria Environmental Management Program (LVEMP)

This regional program being implemented by the three riparian countries around Lake Victoria is one of the largest forms of environmental conservation interventions in and around the lake. The program was initiated in response to the eminent ecological collapse of the lake resulting from a number of adverse effects on the water quality and fisheries biodiversity. With its several research, capacity building, environmental management and development components the program is being implemented by several national ministries and organizations in Kenya, Uganda and Tanzania. Details of the program are in the project document but it is worth mentioning here that the program will need to target more efforts on research on biodiversity degradation, conservation and related socio-economic situations in the lake and its basin.

6.1.9. Other National organizations

These exist in Uganda and Tanzania especially TAFIRI in Tanzania and FIRI in Uganda but are not reviewed, though they may be mentioned in this text in relation to regional collaboration efforts on Lake Victoria fisheries research. The recently

formed Lake Victoria Fisheries Organization (LVFO) will hopefully greatly enhance conservation, research and sustainable management of fisheries resources in the lake. LVFO was established in 1980 to provide a forum for regional collaboration in the development and management of the fisheries of Lake Victoria. The organization is an independent inter-governmental organization that aims to harmonize national measures for the sustainable utilization of the living resources of the Lake and provide a forum for discussion of the impacts of initiatives dealing with the environmental and water quality in the Lake basin.

6.2. Non-Governmental and international Organizations

6.2.1. Lake Victoria Fisherfolk Association

This organization has just been registered by the Kenya Government. Its main objective is not to conduct research but to form a strong partnership of the Lake Victoria local fisherfolk with other institutions (or on their own) in decision making, planning, implementation and evaluation process of fishery policy, management and conservation. Furthermore, the association aims at effectively lobbying and advocating on behalf of the fisherfolk for a positive change of events especially in respect to conservation and sustainable use of the lake's fisheries resources. The formation of this organization is seen by the patrons as a means of averting both environmental and economic crisis's now facing the fishing communities along the Nyanza Gulf. From biodiversity research stand, this institution comes in at the right time when there is need to involve the fisherfolk in community based research, conservation and sustainable use of Lake Victoria fishery resources.

6.2.2. Friends of Lake Victoria (OSIENALA) Environmental Program

This is a Kenyan based organization registered in 1993 to fight the environmental degradation of Lake Victoria and its environs. Since its inception OSIENALA has carried out projects such as the implementation of the UNDP/GEF supported Lake Kanyaboli rehabilitation program and Sondu Miriu/Nyando wetland conservation project. It has also been conducting numerous local and regional training and workshops on the conservation of lake's fisheries resources. Through these efforts OSIENALA has also put into place a number of valuable publications concerning the lake conservation and has been lobbying for participation in the regional Lake Victoria Environmental Management Program (LVEMP), (OSIENALA 1995). A lot of OSIENALA's work has been associated with socio-economic issues and biodiversity loss in Lake Victoria without necessarily linking the two. In Eastern Africa OSIENALA remains a grassroot institution concerned with community based environmental conservation activities around Lake Victoria. There are no similar community based NGOs in Uganda and Tanzania and it would be of interest to have such organizations started to complement efforts being made by OSIENALA in Kenya.

6.2.3. Kenya Energy Non-Governmental Organization (KENGO)

This is an old institution as far as Kenyan environmental management is concerned. Through its Lake Victoria Regional Program (Uhai), Kengo seeks to conduct research and involve community participation in conservation of the lake's vast but fast dwindling resources. Kengo has published a number of policy, socio-economic and scientific papers on Lake Victoria environmental conservation. Indeed it is out of KENGO's 10th anniversary celebrations, in Kisumu, that OSIENALA was born and the two institutions have continued to work together, especially in the area of energy saving technology. This requires more socio-economic and scientific research since smoking Nile perch and other fish species demand much woodfuel and is already threatening the fragile terrestrial biodiversity around the lake. Furthermore, the indigenous tree species that are preferred for use in smoking fish are also valuable for medicinal, furniture, domestic fuel and for nesting by numerous and rare bird species found within the fringes of Lake Victoria.

6.2.4. Fresh Water Biology Association, England

Since its inception in the 1930's the Freshwater Biological Association has been involved in research on African lakes and rivers. Its research has included general and multidisciplinary surveys of many lakes including Lake Victoria, Lake Tanganyika, Lake Malawi and Lake George. The hydrobiology of the River Nile has also been studied. Research into physical and chemical limnology, phytoplankton ecology and primary productivity, invertebrate biology, freshwater fish and fisheries has been a major research focus by the institution.

6.2.5. IUCN Project on the Nile perch Fishery on Lake Victoria

IUCN has had its regional office in Nairobi since 1985, which facilitates regional programmes in Eastern African including research on Lake Victoria. Currently IUCN is conducting Socio-economic studies of Lake Victoria fisheries in collaboration with government institutions and NGOs in the regional basin. This project continues to generate a series of valuable publications under the title of "Socio-economics of Lake Victoria Fisheries". Two such publications were used for the this report:

1. Jansen E.G. 1997. *"Rich Fisheries - Poor Fisherfolk: Some preliminary observation about the effects of trade and aid in the Lake Victoria Fisheries".*

2. Abila R.O. and Jansen E.G. 1997. *"From Local to Global markets: The fish exporting and fishmeal industries of Lake Victoria- Structure, strategy and socio-economic impacts in Kenya".*

There are other local NGOs working around the lake but most of them are recently formed and will take time before their performance and strengths can be reviewed. In the international circle a number of organizations are involved in Lake Victoria biodiversity and socio-economic research. Such include the New England Aquarium conducting research on Lake Victoria cichlids, limnology and aquaculture. The Environmental Protection Agency is yet another organization concerned with the conservation research on Lake Victoria. For a number of years now the USAID/ILOR has been involved in collaborative research work on cichlids & limnology of Lake Victoria the results of which have been published and presented in a number of fora and journals. The FAO/Inland Fisheries Planning Project is also a regional program concerned mainly with stock assessment and improved utilization of Nile Perch in the three East African countries. Other on going studies on the lake are studies on water quality by Kenya/Belgium Joint Research in Fisheries Ecology and the Lake Victoria Fisheries Research Project (LVFRP) on stock assessment supported by European Union (EEC). The University of Michigan through its Program on the Lakes of East Africa (PLEA) has been conducting socio-economic studies on Lake Victoria fisheries for some time now. Lake Victoria fisheries research has also received numerous funding support from such various international donors, such as IDRC, IFAD, UNDP, FAO, EEC, etc. the details of which are beyond the scope of this review.

7. KNOWLEDGE GAPS AND AREAS FOR FUTURE RESEARCH

Although this review is by no means exhaustive two major issues seem to emerge as research gaps in this area. Firstly, the socio-economic work so far conducted and that in progress are not directly related to the lake's biodiversity. Secondly, information is still lacking on the fisheries events before the introduction of the Nile perch. Additionally, it was found that although a large body on information and date exists within several institutions and with individual researchers which are neither analyzed nor published. These include some biodiversity and socio-economic studies on Lake Victoria Fisheries. Other areas that need detailed research include the need to study biodiversity as affected by the Nile perch and the relationships between the fast changing biodiversity, food web and terrestrial/wetland non-fisheries species in relation to their socio-economic implications and community coping strategies in the region. These areas would be of great value in planning future research for conservation and sustainable management of the lake's biological resources. Below is a summary of knowledge gaps identified from this review and recommendations for future biodiversity and socio-economic research work in the Lake and its environs.

1. Lake Victoria is surrounded by rich indigenous plant species including trees, shrubs and grasses which constitute the neighboring terrestrial and wetland habitats. The present fisheries and fish processing methods through smoking seem to exploit these resources due to lack of alternative energy sources in this region. There are indications that these plant species are fast declining and their alternative uses are bound to dwindle. The biodiversity and socio-economic implications which are beginning to emerge is yet to be studied.

2. Avian biodiversity in and around the lake is not well understood to date. This information is essential as we seek to understand the changes in food chain and avian habitats which continue to be destroyed by human induced degradation of the Lake's biological resources. The wetlands and associated vegetation continue to act as stable habitats and food source for many birds species. There is evidence that changes have occurred in the feeding behavior and diet composition as well as the nesting activities of some bird species as

a result of the changing fisheries diversity and declining habitats in the lake and around the lake. Research work is needed to ascertain the socio-economic and biodiversity implications of these changes in order to plan for conserving the rich avian diversity in the basin. For instance, it would be useful to study the changing perching behavior and resting sites of birds as the trees are being cut for fuelwood and wetland are being reclaimed or as some rivers such as Sondu/Miriu are being dammed for production of hydro-electric power. Research is required on the changes in the aquatic birds feeding behavior and types of fish species being fed on.

3. Changes in the Nile perch feeding behavior and those of other fish species appear to occur in relation to the changing ecosystems in the lake. There is need to start monitoring the changes in prey species diversity by gut analysis. This will help in suggesting to what extent such changes are affecting the diversity of prey and their sizes. As yet there is no evidence that sufficient baseline data exists on this important area.

4. Changes in population structure of the Nile perch fisheries need to be intensified as the fishing pressure increases and the consequent impact on the diet of the Nile perch and the fisheries biodiversity, with special emphasis on regional relationships in time and space.

5. Due to the changing fisheries in the lake, the riparian communities are becoming more dependent on fish processed products especially their by-products for their income and subsistence. Socio-economic research in this is still inadequate, particularly with respect to affordable sources of protein and income generation.

6. It is well known that Lake Victoria and its catchment is rich in biodiversity and that this rich resource is fast declining. The problem is that to date there is no authoritative catalogue on the indigenous biodiversity of the lake and associated wetlands that would assist in continued evaluation, monitoring and updating the status of biological integrity of the lake. It would also be of great significance to conduct studies that would lead to establishing indicator species in the lake for assessing ecological changes in cases of further degradation or as a measure of conservation efforts; e.g. chironomid communities and other secondary consumers which occur in the lake are not well studied to date. There is also a need to study other groups of fish, frogs and arthropods such as dragon flies that could act as indicator species and to give a general picture of dominant species to work with in future.

7. Most socio-economic and ecological work so far reported do not give much information on the biodiversity of wetlands associated with Lake Victoria and yet this is a major ecosystem which still contains diverse biological resources. These resources continue to be over-exploited but limited research work is being conducted to elucidate the problem and suggest solutions. It is well known that this habitat is still the major refuge for many indigenous species thought to be extinct or threatened. Evidence from fishermen now indicate that some juveniles of the Nile perch already inhabit the wetlands, posing further threat to indigenous fish. Research work is recommended in this area to determine the relationship between the diversity of wetland species and the effects of Nile Perch. Further, within the wetlands, there exists animal/human and human/human conflicts in relation to the use of wetland for farming and exploitation of its resources.

8. Despite the current knowledge and utilization on biological resources world wide, little or no information is available on views and attitudes of local peoples on biodiversity within fisheries. No research seem to be in place on the values people put on different species, fisheries and local names given to various important species. For instance, there is need to relate the socio-cultural and economic values of different fish species e.g. most to least valuable. It would also be of interest to study and determine certain socio-economic indicators of biodiversity amongst the local fishing communities i.e. related social status and types of fish eaten by a given family.

9. It is also observed that various institutions work independently on different aspects of the lake. Much data related to biodiversity and socio-economics may have been generated in this way but not analyzed and published. For instance, the institutions reviewed above have substantial amount of data which are still on the shelves. It is recommended that such data be looked into, analyzed and published to help bridge the present information gaps.

Further, most of the work used for this review is still in preliminary state and may not be authoritatively quoted. Although they provide a good reference to the type of work going on in Lake Victoria, there is need to evaluated their significance, accuracy and reliability as base line information for future research. It is suggested that further consultancy work will greatly assist in compiling this information and presenting them as publications.

10. To date there is much proliferation of Non-governmental Organizations (NGOs) and programmes seeking to contribute to the conservation of lake Victoria or just gambling to benefit from the donor support targeted for conservation of the lake. There is need to evaluate the contribution of such institutions so as to consolidate their efforts. While in Kenya, OSIENALA poses a strong presence in the Nyanza Gulf and is today venturing into regional and international matters on the lake, such an institution is lacking in Uganda and Tanzania. It is recommended that NGOs of the caliber of OSIENALA be formed in these countries to complement these efforts at the grassroot level and ensure regional collaboration between the riparian communities. Such organizations should be targeted by the international funding agencies to strengthen their management and to ensure grassroot participation on various socio-economic and biodiversity conservation issues of the lake.

11. Despite the new efforts on the establishment of the East African Community, there are still gaps that if filled would facilitate free flow of research information and networking between the different institutions and individuals working on the biodiversity and socio-economics of Lake Victoria. Fortunately, the LVEMP and the LVFO are attempting to bridge these gaps, but a lot still remains to be done. Future research in these areas will require expansion of range of visits between Kenya, Uganda and Tanzania and exchange of information between government institutions, universities and NGOs involved in research on Lake Victoria.

8. CONCLUSIONS

Certainly, substantial research work has been done on Lake Victoria fisheries and socio-economics. Most of this has targeted the exploitation of the fisheries resources in the lake. Some recent work has been done on the biodiversity of the lake but a lot remains to be done. Of particular interest would be the relationships between the lake's biodiversity and socio-economic studies, which is still wanting. The great pressure placed on the lake's resources by the heavy populations around the lake calls for investigations on the coping strategies of the riparian communities and conservation plans for the future. Despite the recent establishment of LVEMP, which by nature of its implementation excludes many stake holders, there is need to forge strong linkages between the riparian communities to help facilitate data gathering. For instance there is need to form comparable NGOs in Uganda and Tanzania to complement the efforts of OSIENALA in Kenya. There is also need to form stronger research linkages and exchange visits between the different institutions working on Lake Victoria. From this study it may be concluded that there is still much scope for socio-economic and biodiversity research in Lake Victoria and its catchment basin.

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Annex 2. INDIVIDUALS ASSOCIATED WITH BIODIVERSITY AND SOCIO-ECONOMICS RESEARCH ON LAKE VICTORIA

1. Persons and Contacts in Kenya

Abila, Richard - Socio-Economics of Lake Victoria fisheries, KMFRI, Kisumu, Kenya.

Asila, A. (1992) [KMFRI, Kisumu]; M.Phil. candidate, Currently working on Selectivity of gill nets on Nile Perch in L. Victoria (KMFRI/Moi Univ.).

Gutwa, G.K. (1998) Marketing of fish and fish by-products and their impact on Lake Victoria lakeside communities, KMFRI, Kisumu,
Kenya.

Olulu H. O. -Managing fisherfolk union with cold storage facilities for Nile perch. Suba District Co-operative Union. P.O. Box 205, Homa Bay.

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Mary Onyango; Working on the uses of water hyacinth - for making furniture and ornamentals. This is useful for sustaining livelihood of the lake basin inhabitants. [Kisumu Innovative Centre, P.O. Box 284, Kisumu].

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Mwalo, Osborn, M.Sc., D.Phil. candidate- Currently working on abundance and quantifying the effect of lighting on Omena catch.

Njiru, M.Phil. D.Phil.candidate-Biodiversity in L. Victoria. Moi University / KMFRI.

Ocholla Kapiyo Ph.D. KENGO -Lake Victoria Community Environmental Programmes-Uhai Lake region Programmes. P.O. Box 6025, Kisumu.

Ogari, J. (1992) Processes, faunal changes and management measures for the Kenya sector of Lake Victoria. Paper presented in Biodiversity, Fisheries and the Future of Lake Victoria, Jinja, Uganda, Aug. 17-20, 1992. KMFRI, Box 1881, Kisumu.

Okallo, Dick B.A., M.Phil candidate, Currently working on the Socio-Economics of the water hyacinth on L. Victoria fisheries.

Okoth, P.G. (1996) Socio-Cultural and economic Constraints in the development of the Lake Victoria region. Centre for the Study of Lake Victoria and its Environs, Maseno Univ. Coll, Private Bag Maseno, Kenya.

Omondi, Reuben B.Sc, M.Phil. candidate, Currently working on Taxonomic description of cladosela and copepods in L. Victoria's Nyanza Gulf, KMFRI/Moi University, P.O. Box 3900 Eldoret.

Onyango, Sebastian Ochieng', M.Phil. Aquatic Ecology and Fisheries Management. The role of fisheries Department in the conservation of biodiversity in Kenya with particular reference to the Lake Basin Region. Fisheries Dept. Min. Nat Resources, Kisumu.

Oyieke, Hilda, PhD. Lake Victoria Biodiversity Research, National Museums of Kenya, Nairobi.

Raburu,O P. M.Sc. D.Phil (scholar). Drp. of Fisheries, Moi University, P.O. Box 3900, Eldoret. Biodiversity of fish in Nyando Wetland.

Rasowo, Joseph Ouma,PhD, wants to enterprise rice/fish farming in the Nyando Plains (Funding from Support Africa). Moi University Fisheries Dept. P.O. Box 3900 Eldoret.

Rinne, J.N. (1980) Notes on the occurrence and biology of *Xenoclarias* Greenwood (Siluriformes: Clariidae) in Lake Victoria, East Africa. East African Freshwater Fisheries Research Organization, Kisumu, Kenya.

Wangila,B.C. PhD. Fish Geneticist. Starting to look at the effect of water hyacinth on the abundance of fish in L. Victoria.

Yongo, Ernest (1998) The impact of changing fish species on nutrition and health of lakeside communities. KMFRI, Kisumu, Kenya.

2. Persons and Contacts in Tanzania:

2.1. Tanzania Fisheries Research Institute P.O. Box 475, Mwanza;

a. E.F.B. Katunzi, M.Sc. Centre Director, Tanzania Fisheries Research Institute (TAFIRI) Mwanza Station.

b. Mahongo, B.Sc. Oceanographer, (TAFIRI, Mwanza) .

c. Mary Kishe, B.Sc.

d. Mukumbo, M.Sc. Stock Assessment (TAFIRI, Mwanza).

e. Nsinda, B.Sc. Stock Assessment (TAFIRI, Mwanza).

f. Yohana Budeba, M.Sc, Limnologist (TAFIRI, Mwanza).

3. Persons and contacts in Uganda:

Basasibwaki, P. Uganda Fisheries and Forestry Research Organization (UFFRO), Jinja. Research on abundance and species composition of haplochromines in Lake Victoria.

Byarujali, S.M. Dept. Bot. Makerere, P.O. Box 7062 , Kampala - Diatom species diversity.

Katonda. K.I. Deputy Executive Secretary. Lake Victoria Fisheries Organization (LVFO). Jinja, Uganda.

Kateyo, E.M. Institute Environment & Natural Resources., Makerere University, P.O. Box 7062 Kampala. Research on Crustaceans of Lake Victoria.

Mbahinzireki. G.B. (1992); UFFRO Box 343, Jinja, Uganda: Research on the benthic communities of northern Lake Victoria.

Micheni J. Ntiba, PhD. Lake Victoria Fisheries Organization. Jinja, Uganda.

Mwembaza-Ndawula, L. (1992) [UFFRO, Box 343, Jinja] Research on distribution, abundance and changes in relative abundance of zooplankton in northern Lake Victoria.

Annex 4. Institutions involved in supporting research on Lake Victoria Fisheries

1. European Union (EEC) Lake Victoria Fisheries Project Stock Assessment.

2. FAO - Improved Utilization of Nile Perch.

3. FAO/Inland Fisheries Planning Project Pelagic Fisheries (*Rastrineobola argentina*).

4. Haplochromine Ecology Survey Team (HEST) & University of Leiden (Tanzania) Haplochromine.

5. IDRC - Fish systems (Uganda/Tanzania).

6. IFAD- Uganda: Project.

7. IUCN-EARO; regional project on the "Socio-economics of the Nile perch Fishery in Lake Victoria"

8. Kenya Belgium Joint in Fisheries Ecology Water quality.

9. Kenya Marine Fisheries Research Institute Haplochromine.

10. UNDP/ Belgium survival Fund. - Development of Small Scale Fish Farming Program: Lake Basin Development Authority.

11. New England Aquarium (Kenya Uganda and Tanzania). Cichlids, Limnology, aquaculture.

12. UNDP - Lake Kanyaboli/Project Yala Swamp.-OSIENALA.

13. University of Michigan Socio-Economics: FLEA (Dr. D.C. Wilson).

14. USAID/ILOR -Israeli Limnological & Oceanography Research Limited Cichlids & Limnology.

15. Wetland Ecologist National Environment Management Council (NEMC).

16. Kenya Wildlife Service (KWS) - Nyando Wetland Biodiversity Conservation Research Program.

17. Kinneret Limnological Lab-Israel and Harvard University respectively] Changes in oxygen availability in the Kenyan portion of Lake Victoria: Effects on fisheries and biodiversity.

IUCN - The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 900 members in all, spread across some 138 countries. As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. The Union has helped many countries to prepare National Conservation Strategies, and demonstrates the application of its knowledge through the field projects it supervises. Operations are increasingly decentralized and are carried forward by an expanding network of regional and country offices, located principally in developing countries.

The Eastern Africa Regional Office

IUCN established the Eastern Africa Regional Office (EARO) in Nairobi in 1986 which facilitates the Regional Programme. EARO covers Kenya, Tanzania, Uganda, Ethiopia, Eritrea, Sudan, Somalia, Djibouti, the Seychelles and Comoros. Through its technical group, established in the early 1990s, EARO assists members and partners in the region with capacity building through the implementation of projects and programmes, networking and technical advice. Specific areas of expertise include: protected areas, ecosystem management, biodiversity conservation, environmental planning and strategies and support to environmental NGOs.

Socio-economics of the Nile Perch Fishery on Lake Victoria

One of the many projects within the Eastern Africa Programme of IUCN is the Socio-economics of the Lake Victoria Fisheries. The project's objectives include: understanding the socio-economic conditions of various stakeholders in the Lake Victoria fishery and building capacity to manage the fishery in a sustainable and equitable manner – with involvement of the local communities. The project is being implemented in collaboration with government research institutes and local NGOs in East Africa (Kenya, Tanzania and Uganda). The project has its own publication series entitled "Socio-economics of the Lake Victoria Fisheries".

The following reports have appeared:

1. *Rich Fisheries – Poor Fisherfolk: Some Preliminary Observations about the Effects of Trade and Aid in the Lake Victoria Fisheries,* by Eirik G. Jansen
2. *From Local to Global Markets: The Fish Exporting and Fishmeal Industries of Lake Victoria – Structure, Strategies and Socio-economic Impacts in Kenya,* by Richard O. Abila and Eirik G. Jansen
3. *Trawling in Lake Victoria: Its History, Status and Effects,* by James Siwo Mbuga; and Albert Getabu, Andrew Asila, Modesta Medard and Richard Abila
4. *Traditional and Central Management Systems of the Lake Victoria Fisheries in Kenya,* by John P. Owino
5. *A Review of Biodiversity and Socio-economics Research in Relation to Fisheries in Lake Victoria,* by Okeyo-Owuor. J.B.
6. *Constraints and Opportunities for 'Community Participation' in the Management of the Lake Victoria Fisheries,* by Eirik G. Jansen, Richard O. Abila and John P. Owino

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