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Yunus D. Mgaya
Shigalla B. Mahongo *Editors*

Lake Victoria Fisheries Resources

Research and Management in Tanzania

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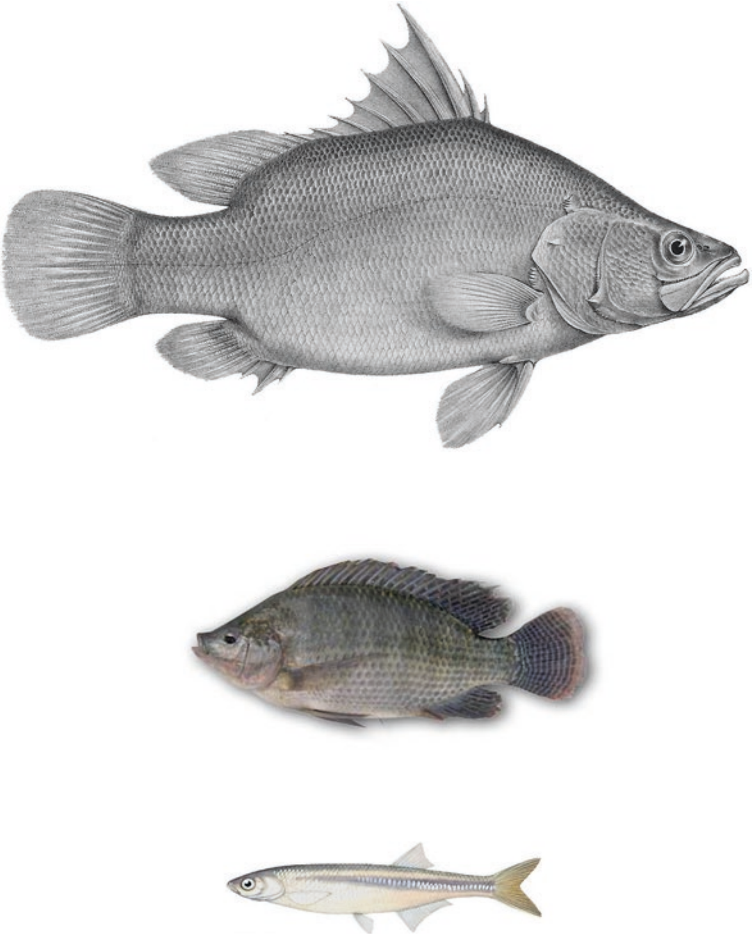

Lates niloticus (top)
Oreochromis niloticus (middle)
Rastrineobola argentea (bottom)

Preface

This book has benefitted from the implementation of Phase I of the Lake Victoria Environmental Management Project – LVEMP I (1997–2005), complemented by previous research undertakings on the lake, including the Lake Victoria Fisheries Research Project (LVFRP) and the Haplochromine Ecology Survey Team (HEST). The LVEMP I was conceived to arrest and address problems that threatened the sustainable development and utilization of the lake basin resources. The project implementation framework comprised eight components in each of the three riparian states of Kenya, Tanzania, and Uganda, namely, fisheries research, fisheries management, water quality and ecosystem management, wetlands management, integrated soil and water conservation, capacity building, community participation, and micro-projects. A large volume of data and information that were generated during the eight years of the implementation of Phase I from July 1997 to June 2002 and a bridging period from July 2002 to December 2005 prompted the three riparian states of Kenya, Uganda, and Tanzania together with the Global Environment Facility (GEF) and the World Bank to consider carrying out an exercise to analyze, consolidate, and synthesize data and knowledge generated during the period. This assignment was accomplished through a consultancy, which involved one regional consultant and the editor of this book (YDM) as the national consultant assisted by coordinators and task leaders of the LVEMP I project, under the overall coordination of the Secretariat.

The work in this book derives mainly from the two components of fisheries research and fisheries management and was initially produced as a synthesis report of the two components just before the completion of the project in 2005. Although the draft document was first produced in 2005 as a synthesis report, it was not published during the project implementation period as resources were by then not available to facilitate its publication. The publication of this book would not have been possible without the financial assistance from the University of Dar es Salaam and the full support of the publisher, Springer International Publishing AG. It should be noted that, even though a significant amount of time has passed since the synthesis report was produced, the information in this book is based on current and up-to-date data on the evolution of fisheries resources in Lake Victoria, Tanzania.

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Acknowledgments

While it is not possible to mention every institution and individual who, in one way or another, contributed to this work, there are a few we would be remiss not to mention. The preparation of this book, which is based on a 2005 synthesis report of LVEMP I, was the result of a collective effort involving staff from the Fisheries Development Division and Tanzania Fisheries Research Institute (TAFIRI) and supported by funds from the World Bank (GEF/IDA) through LVEMP I. The necessity of the synthesis report was prompted by a decision of the Regional Policy and Steering Committee, which required the riparian countries to carry out the task of preparing national synthesis reports on various themes including fisheries research and fisheries management. We are deeply indebted to the LVEMP Regional and National Secretariat in Dar es Salaam for their commitment to the synthesis report and, in particular, the regional/national executive secretary, Mr. Christopher Nyirabu, and his staff, without whom the successful completion of the report would never have been possible.

The production of the chapters in this book would not have been possible without the collaborative support and inputs from the Fisheries Development Division and TAFIRI. To this end, we would like to extend our sincere gratitude to the Director of Fisheries and the Director General of TAFIRI for their full support including the project component coordinators, task leaders, and the rest of the staff who all worked efficiently to provide the necessary data and information. Many thanks to Prof. Jeppe Kolding from the University of Bergen, Norway, and Prof. Paul van Zwieten from Wageningen University, the Netherlands, who played vital roles in guiding the chapter authors, especially in the initial stages, and provided many useful contributions. Our special thanks go to Prof. Ian Cowx and Mr. Robert Sululu whose critical reviews improved the manuscript substantially. We are very grateful to Advocate Baraka Yunus Mgaya and Dr. Gastor Mapunda for the English language editing and Mr. Masumbuko Semba for the technical support and help with graphics during the preparation of the book manuscript.

This book benefited immensely from a wealth of information generated by various projects and organizations on Lake Victoria, including the Lake Victoria

Fisheries Research Project (LVFRP), the International Union for Conservation of Nature (IUCN), and the Haplochromine Ecology Survey Team (HEST), to mention but a few. And last but not least, we owe a debt of gratitude to the Water Quality and Ecosystem Management Component of LVEMP, which provided some of the data on water quality like lake level and chemical parameters. Various sources of data are widely acknowledged in the individual chapters.

Contents

Chapter 1
Introduction

Yunus D. Mgaya

Abstract Lake Victoria is an important nutritional and socio-economic resource that contributes significantly to the economies of the riparian countries and communities. The lake is important for transportation of goods and services among and within the riparian states; biodiversity conservation; water for domestic, agricultural and industrial use; and aesthetic values. Its fishery resources are noteworthy as sources of livelihoods, employment, and foreign earnings to the riparian states. Nonetheless, Lake Victoria has experienced drastic changes in water quality, biodiversity, fisheries and wetlands due to high population pressure, unsustainable socio-economic and poor land-use activities. Fish stocks and biodiversity have declined, and eutrophication has caused rampant algal blooms and poor water visibility. These environmental concerns prompted the riparian states of Kenya, Tanzania and Uganda to formulate the Lake Victoria Environmental Management Project (LVEMP I), and sign cooperation frameworks for the management of the lake and its basin. They aimed for rational utilisation and conservation of Lake Victoria through joint monitoring and management of the resources, rehabilitation of the ecosystems within the basin, and achieve environmentally and socially sustainable economic development of the states. LVEMP I started in 1997 and was implemented nationally but coordinated regionally within the scope of the East African Community Treaty.

This book compiles, synthesizes and documents change in water quality, biodiversity, fisheries, and fish processing and quality control that have occurred over the recent decades. It provides an overview of the present knowledge and status of the fish and fisheries of the lake, and proposes measures for monitoring or remedial actions.

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1.1 Background

Lake Victoria is the largest tropical lake in the world with a surface area of 68,800 km^2 (Bootsma and Hecky 1993). Three countries share the lake, with a 51% share in Tanzania, 43% in Uganda, and 6% in Kenya. The lake is roughly square in shape, its greatest length and width being approximately 400 and 300 km respectively. It lies at an altitude of 1,135 km above sea level and situated between the great plateau that stretches between the western and eastern branches of the Rift Valley. The lake is relatively and predominantly shallow (maximum depth, 96 m in the northeast, average depth, 40 m). It has a total catchment area of 193,000 km^2, which is shared between Tanzania (44%), Kenya (22%), Uganda (16%), Rwanda (11%), and Burundi (7%) (Government of Kenya, GoK/Government of Uganda, GoU/ Government of Tanzania, GoT 1996). The shoreline of the lake is approximately 3,450 km, with 50% (1,750 km) in Uganda, 33% (1,150 km) in Tanzania and 17% (550 km) in Kenya. A thick layer of organic mud forms the main part of the lake bottom, which also has patches of hard substrates, sands and/or rocks (Scholz et al. 1990). The shoreline has numerous sheltered bays and gulfs, which make it very irregular and heterogeneous, thus affecting ecological differentiation to the lake limnochemistry and biota.

The drainage basin on the Tanzanian part of Lake Victoria is characterised by small (satellite) water bodies, which include Lake Malimbe and the lower Kagera lakes complex and flood swamp (lakes Rushwa, Kalenge, Katwe, Ikimba, Burigi, Rwakajunju and Ngoma), the Masirori swamp (Lake Kubigena) and the Kirumi ponds. Major rivers draining into Lake Victoria are Mara, Mori, Grumet, Simiyu, Rubana, Suguti, Ngono, Magogo, Mbalageti, Mwame and Kagera (Fig. 1.1). These satellite water bodies are shallow with a maximum depth ranging from 1.8 to 8 m (Katunzi 1998).

Lake Victoria and its inflowing rivers contribute significantly to ecological, biophysical, cultural and socio-economic development along its shoreline, catchment area and islands as well as the livelihoods of the communities far and beyond its catchment area. The lake supports Tanzania in terms of food, transport and communication, tourism, water supply for domestic, agricultural and industrial use, wastewater disposal, recreation, sports and biodiversity conservation. The lake is also vital for weather and climate modulation. The dominant socio-economic activities in the lake and its catchment include agriculture, fisheries, marine transportation, recreation, and water supplies for domestic and industrial use in the urban centres on its shoreline. Agriculture and fishing remain the dominant socio-economic activities of most of the population within the catchment area. However, mining is also an important economic activity around Mwanza, Mara and Kagera (e.g. Tulawaka in Biharamulo) Region. Urban development (Mwanza, Bukoba and Musoma) is also on the increase.

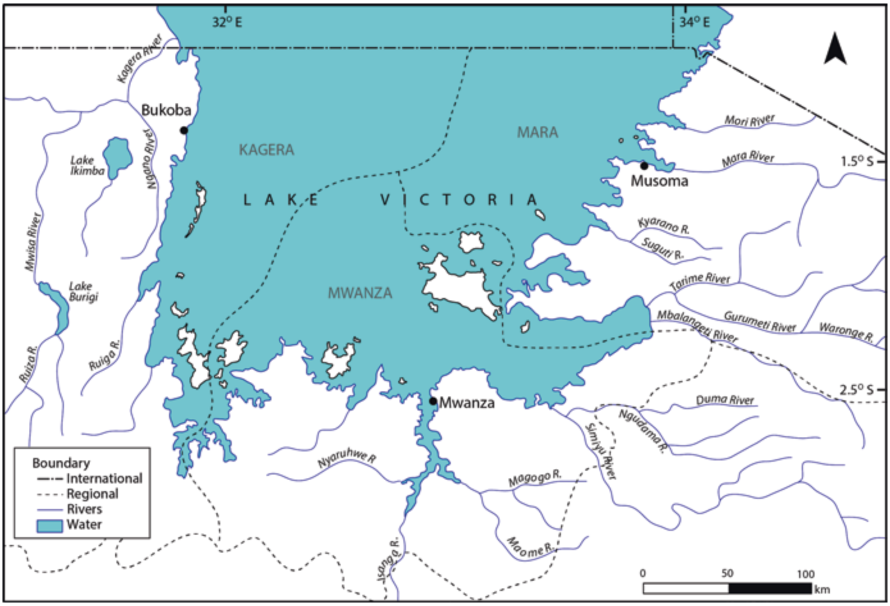

Fig. 1.1 Map of Lake Victoria (Tanzania) showing the major rivers, catchment area and urban centres

Lake Victoria is endowed with invaluable fishery resources that are contributing enormously to the livelihood of the communities and the riparian states in terms of food security, employment, wealth generation, foreign earnings and other multiplier effects. The Tanzanian side of the lake accounts for over 60% of the total national inland fish production and contributes >250,000 mt of fish annually. Fish and fishery products from this lake provided a significant quantity of protein/food, which amounted to 262,572.06 mt and valued at more than TZS 81.6 billion in 1996 (Fisheries Development Division 1997). In 2016 the total Nile perch and its products exported from Lake Victoria was 26,044.7 mt, which generated about TZS 345.4 billion (Fisheries Development Division 2016).

The lake provides income and employment to over 109,000 full time fishermen who operate a total of 30,139 vessels (Fisheries Development Division 2016) while over 500,000 people are employed formally or informally in fisheries related activities. In addition, there are more than four million people living in the Tanzania catchment of the lake and other millions in other parts of the country who benefit directly or indirectly in the form of food or income from the lake's fisheries. The lake is also an important source of water for domestic, industrial and small-scale agriculture. It is also an important transport corridor between major towns around the lake and a number of villages, settlements, beaches and numerous islands.

1.2 History

1.2.1 Lake Victoria Environmental Management Project

Lake Victoria used to have a rich well-balanced fish species complex prior to the 1960s. Post 1960s is characterised by greatly changed fish species composition (Downing et al. 2014). The haplochromine, which was the most dominant species flock, was reduced to near extinction and only pockets of some species may be seen in protected bays and inlets acting as refugia (Witte et al. 1992). The two endemic species, *Oreochromis esculentus* and *O. variabilis* have almost disappeared in the lake. Non-cichlid endemic genera, which were well represented, but are now seldom seen, include *Barbus, Protopterus, Mormyrus, Labeo, Gnathonemus, Rastrineobola, Synodontis, Clarias, Bagrus, Schilbe*, and *Alestes* (GoK/GoU/GoT 1996).

Many reasons have been advanced for the disappearance of important fish species in Lake Victoria; but certain events in the lake can be directly associated with species decline. There has been an introduction of exotic tilapiines, notably *Oreochromis niloticus, O. leucostictus, Tilapia zillii* and *T. rendalli*, in the 1950s and 1960s. In addition, there was an introduction of the voracious Nile perch, *Lates niloticus,* into the lake in the mid 1950s, the ecological consequences of which are still being felt to date. Furthermore, bad fishing practices and overfishing have contributed greatly to the decline of the Lake Victoria fish species; and the degradation of the environment—leading to siltation, eutrophication and pollution—has contributed to the species' inability to successfully use habitats for survival and select their mates (GoK/GoU/GoT 1996; Seehausen et al. 1997; Downing et al. 2014).

Increasing population pressure and socio-economic activities in the lake basin have resulted into changes in land use, water quality, biodiversity, wetlands and fisheries. Fish stocks have been changing, biodiversity has declined, algal blooms are frequent and turbidity, which reduces water transparency, continues to increase due to increased eutrophication. The water hyacinth, *Eichhornia crassipes*, which is now in decline, continued to spread over the lake almost uninterrupted. It thus interfered with light penetration, dissolved oxygen distribution, and reduced fish breeding sites. Moreover, it blocked fish landing sites and recreation beaches, while affecting lake transport and the lake ecosystem in general (GoK/GoU/GoT 1996).

Furthermore, industrial effluents, domestic and urban wastes, sewage, land degradation, destruction of wetlands and urban and agricultural run-offs are continually polluting the lake. Soil erosion became a major problem in the Lake Victoria Basin, which led to serious water pollution from high concentrations of dissolved phosphates, nitrates and pesticides as well as increased sediment loading into the lake.

It was realised that the environmental concerns, described herein, needed to be addressed through an integrated effort. The three riparian states further realised that the rational utilisation and conservation of Lake Victoria can only be achieved through cooperation in planning, exploitation, management, and monitoring of the resources. Unfortunately, previous efforts on joint management collapsed with the demise of the East African Community in 1977. Threats to the lake ecosystem, however, continued unabated. This prompted the Governments of Kenya, Uganda and Tanzania to initiate plans for the formulation of the Lake Victoria Environmental Management Project phase I (LVEMP I). Subsequently, on 5th August 1994 the three Governments signed a tripartite agreement that led to a cooperative framework for the management of the lake and its basin. Consequently, LVEMP I was started in 1997 as a five-year project with the main aim of rehabilitating the ecosystems in and around the lake and a long-term objective to introduce environmentally and socially sustainable economic development in the three riparian countries. The LVEMP I was designed as a comprehensive and holistic regional development programme and was implemented nationally in three countries but coordinated regionally within the scope of the East African Community Treaty.

Some of the major threats to the ecosystem of the lake that the three countries addressed originate from the following:

- Deterioration of water quality
- Land degradation resulting from poor agricultural practices
- Deforestation
- Destruction of wetlands
- Inadequate collection and treatment of industrial and municipal wastes
- Infestation with water hyacinth
- Unsustainable fishing and fish processing practices
- Inadequate human and institutional capacities for research and management functions
- Insufficient awareness on existing policies concerning the lake and land use

The fundamental objective of the LVEMP I was to restore a healthy and diverse lake ecosystem that is inherently stable and that can sustainably support the many human activities in the catchment areas and on the lake itself. The four specific development objectives were to:

- maximize the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and income, safe water supply, and sustain a disease-free environment;
- conserve biodiversity and genetic resources for the benefit of the riparian, regional and global communities;
- harmonize national and regional management programmes in order to achieve the reversal of environmental degradation to the maximum extent possible; and
- promote regional co-operation on the three issues.

In addressing the environmental problems facing Lake Victoria, the following immediate objectives constituted the priority areas of the LVEMP I:

- to build human capacity in order to ensure the sustainability of practices being initiated;

- to build institutional capacity so that the required tools are available for project implementation;
- to create a reliable baseline information/data in order to build on trends for remedial actions;
- to pilot suitable environmental management measures for adoption on a basin-wide scale; and
- to encourage the application of tested lake-wide environmental management practices.

Technically, LVEMP I was implemented through activities that were spread across ten components, which included Fisheries Research and Fisheries Management. Other components were the establishment of the Lake Victoria Fisheries Organization, Water Hyacinth Control, Water Quality and Quantity Monitoring, Industrial and Municipal Waste Management, Wetlands Management, Catchments Afforestation, Land Use Management and Support to Riparian Universities.

1.2.2 Fisheries Research and Management Components of LVEMP I

The objectives of the fisheries research component were to generate and provide information on: (1) the ecology of the lake and its catchments; (2) the biology of its flora and fauna; (3) the impact of environmental factors on the lake ecosystem; and (4) the socio-economic implications of use of the lake's resources. These aimed to ensure the sustainable exploitation and management of the fisheries, conservation of aquatic biodiversity, integration of lake productivity processes into fisheries enhancement and management, reduction of degradation of fish habitats, involvement of communities, and the creation of information centres for dissemination.

The objectives of the fisheries management component were to promote, support, guide and ensure proper management and optimum utilization of the fisheries resources and aquaculture practices in the Lake Victoria basin for the benefit of the riparian population and the global community. Its activities included the harmonization of fisheries regulations of the three countries; identification and establishment of closed fishing areas; and setting up of beach management units (BMUs) to enhance fisheries co-management and to guard against illegal and destructive fishing practices. Others were to establish fish quality assurance laboratories; improve fish handling and processing practices; and the completion of over 115 micro-projects that comprised investments of up to US$ 15,000.00 each in community water supply, sanitary facilities, local roads, health facilities and schools.

1.3 Objectives of the LVEMP I and Justification of Synthesising the Information

The expectations of the project from the outset were that the outcomes of the LVEMP I activities would be to provide information on species distribution and habitat maps; genetic make-up and diversity of the different fish populations; and an understanding of the causes of the decline in fish species. Also to provide an understanding on the impacts of environmental changes on the biology, behaviour and survival of the declining species; guidelines for species conservation and restoration, and an updated bibliography of Lake Victoria and its fisheries. However, it was not possible to generate the information on genetic aspects of fish populations during the lifetime of the project.

During the seven years of the LVEMP I, extensive biotic field surveys were conducted in the three riparian countries and all the data were analysed to provide the required fish biology, fisheries, and biodiversity baseline information. In addition, policy recommendations were formulated and appropriate technologies packaged to address fisheries management issues. This contributed towards improved ecological efficiency, greater biodiversity and ecological balance in the lake ecosystem.

Fisheries research and management components were able to collect large amounts of data and information during the LVEMP I and from other sources. Some of this information was semi-analysed, non-consolidated and inaccessible to other stakeholders. Thus, the objectives of synthesising the information produced during the lifetime of LVEMP I were to:

- Analyze the data in a quantitative manner using appropriate methods;
- Summarize the information gained, and place it in the context of information existing before the LVEMP I and also the information that may have been generated by other entities;
- Consolidate, analyze and synthesize the data and knowledge generated by the LVEMP I and from other sources in order to get a complete picture of past trends and the current status of the fisheries and biodiversity of Lake Victoria and its catchments in line with the expectations of the LVEMP I; and
- Use the available data, information and knowledge to arrive at the expected outcomes of the Fisheries Research and Management Components of the LVEMP I.

The information gathered and lessons learnt, further, did help give direction to the process of preparation of the second phase of the Project (LVEMP II), which was launched in 2009 and has been implemented for 8 years with a scheduled closure at the end of 2017. Moreover, the third phase is already being planned which will ensure continuity of the interventions and further commitment to sustainable management and the restoration of the environment and fisheries of Lake Victoria.

1.4 Scope of this Book and Methodology

The process that led to the development of this book involved mainly two working sessions, which brought together all contributors and a national stakeholders' workshop. These two activities were preceded by an inception workshop, which reviewed the terms of reference of the international and national consultants. Furthermore, the participants determined the outline of the national report; established a time frame for completion of the reports including a common format for report preparation. They also reviewed the data available for the report; assigned responsibilities for writing individual sections of the national report and reviewed and analyzed required data for the complete report.

During the working sessions, the compilation of the various chapters involved the consolidation, analysis, synthesis and the development of trends; the interpretation of data, spatial and temporal variability, inter-species relationships, species' behaviour as well as impacts of environmental changes on biodiversity and the causes of species decline. The writing process involved access to and use of the data produced through the activities of the Fisheries Research and Management Components of LVEMP I, literature sources from libraries and data and information from other entities operating in Lake Victoria. These particularly included the EU-funded Lake Victoria Fisheries Research Project (LVFRP) for the data from trawl and acoustic surveys used in fish stock assessment. Finally, the synthesis report (Mgaya 2005), which marked the end of the LVEMP I, has been revised to form a significant part of this book.

This book documents changes in biodiversity, fisheries, industry and management that have taken place over the recent decades. It provides an overview of the present knowledge and status of the fish and fisheries of the lake, as well as identifying past changes and continuing trends that may require closer monitoring or remedial actions. The aim of the book is to provide detailed information and spatial resolution at the national level to support fisheries decision-making on the lake's fisheries resources. This book is structured in chapters and sub-chapters. There are fourteen chapters in the book including an introduction. The main conclusions and overall recommendations of the book and the status of the Nile perch fishery are presented in the last chapter.

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Chapter 2
Historical Perspectives and Trends in Fisheries Research in Tanzania

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Abstract This chapter traces the history and trends in fisheries research for the Tanzanian part of Lake Victoria and its basin back to the late nineteenth century when the haplochromine species were scientifically identified for the first time. Past studies in the early to mid-twentieth century were mainly designed to address issues related to the introduced species and the abundant haplochromines. Subsequent studies in the late twentieth to early twenty-first centuries integrated multiple disciplines such as fish biology, ecology, biodiversity, limnology, socio-economics and aquaculture. In the late 1990s and early 2000s, lake-wide research projects played a key role in further understanding of the lake-basin flora, fauna and related fisheries. Over the last half century, Lake Victoria has undergone dramatic ecosystem changes, partly driven by the introduction of the predatory Nile perch and the non-indigenous tilapiine species in the 1950s and early 1960s. The profound ecosystem transformation of the lake has also been attributed to cultural eutrophication, climatic variability and over-fishing. In the mid-1950s, the lake had a diverse fish fauna, which was thought to comprise about 29 genera and more than 650 species, with the haplochromines forming about 80% of the demersal fish stocks. Later discoveries in the early 1970s to the late 1990s confirmed that the haplochromine group alone consisted of

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over 500 endemic species. The introduction of the Nile perch was meant to utilize the abundant haplochromines that were considered commercially unimportant, and to extend fishing operations from the inshore to deeper offshore waters.

2.1 Introduction

The Lake Victoria research activities date back to the 1800s and at the turn of the twentieth century (e.g., Hilgendorf 1888; Graham 1929; Worthington 1930). Over the years, the lake has undergone dramatic ecosystem changes resulting in a decline of several fish species, particularly of the haplochromines that used to form over 80% of the demersal ichthyomass in the lake (Kudhongania and Cordone 1974; Ogutu-Ohwayo 1990a, b; Witte et al. 1992, 1995). Haplochromines suffered a 40% loss of biodiversity as a result of predation and competition by the Nile perch, over-fishing and cultural eutrophication caused by industrialization, urbanization and agricultural developments including shoreline deforestation and climatic variability (Witte and Goudswaard 1985; Kaufman 1992; Witte et al. 1992, 2013; Hecky 1993; Pringle 2005; Hecky et al. 2010; McGee et al. 2015; van Rijssel et al. 2016a). These finally caused the disruption of the trophic dynamics of the lake and the consequent accumulation of algae and detritus (Hecky 1993; Hecky et al. 1994; Lowe-McConnell 1992; Ogutu-Ohwayo 1990a, b). At the same time, deep waters became anoxic presumably because of thermal stratification and decomposition of the increased algal biomass (Hecky et al. 1994, 2010; Wanink et al. 2001).

Information on fisheries research on Lake Victoria has been generated through the implementation of a number of projects, which include:

- Haplochromine Ecology Survey Team (HEST) which addressed taxonomic and ecological aspects of the cichlid haplochromines in Lake Victoria from 1977 to 1990;
- Lake Victoria Research Team to address limnological aspects and its impact on species diversity including nutrient loading from 1985 to 1991;
- Food and Agriculture Organization (FAO) of the United Nations funded the project on Improved Utilization of the Nile perch from 1986 to 1990;
- Lake Victoria Species Rescue Project that carried out extensive surveys on the haplochromines and initiated a captive breeding programme for the threatened Lake Victoria fish species from 1990 to 1995;
- FAO funded Inland Fisheries Project Planning that covered Lake Tanganyika and Lake Victoria in terms of fisheries research, planning and development;
- International Union for Conservation of Nature (IUCN) funded Nile perch Project Phase I that collected socio-economic information and disseminated it through a series of Technical Documents from 1996 to 1999;
- IUCN funded Nile Perch Project Phase II that was concerned with information dissemination and developing a network between scientists, media, managers and policy makers from 2001 to 2005;

- Lake Victoria Fisheries Research Project (LVFRP) Phase II that carried out lake-wide trawl and hydroacoustic surveys from 1997 to 2002;
- Lake Victoria Environmental Management Project Phase I (LVEMP I) from 1997 to 2005;
- Implementation of Fisheries Management Plan (IFMP) that has been operating in Lake Victoria from 2005 to 2010; and
- Lake Victoria Environmental Management Project Phase II (LVEMP II) from 2008 (on-going).

Data and information collected by these projects were used to inform several policies and fisheries management both at national and regional levels. For instance, LVFRP-II, LVEMP-I and IFMP were very important in the establishment of co-management structures at grass root levels, establishment of protected areas, mesh and slot size regulations, and ban of trawling among others. The aim of this chapter is to provide historical reviews of some results from the implementation of these projects from both the main lake and satellite lakes.

2.2 Primary Production

In general, Lake Victoria is considered among the highest productive lakes in Africa with high rates of phytoplankton primary production (Mugidde 1992, 1993; Ogutu-Ohwayo et al. 1996). Phytoplankton biomass, evaluated as chlorophyll-*a* or as bio-volume, has increased six-folds or more to values ranging from 2.5 to 660.0 μg/L (Kling et al. 2001) since the 1960s (Talling 1966, 1987; Mugidde 1992, 1993). Low algal biomass composed mainly of diatoms was reported in earlier limnological surveys with offshore chlorophyll-*a* ranging from 1.2 to 5.5 mg/m^3 and 10 to 15 mg/m^3 inshore (Talling 1966). The increase in algal biomass is indicated by higher chlorophyll-*a* concentration. For instance, from the research done in November/December 2003, the values ranged from 124 μg/L at Suguti, and 102.8 μg/L at Nyamirembe to 170.7 μg/L at Mwanza Gulf and Mara Bay (Kishe 2004). In addition, Sitoki et al. (2010) using data collected from lake-wide acoustic surveys from 2005 to 2009 found that chlorophyll-*a* concentrations changed considerably since the 1960s. There was an increase in concentrations of both inshore and offshore waters with average values of 40 μg/L and 60 μg/L in offshore and inshore waters, respectively with maximum concentrations reaching 650 μg/L. Since then, chlorophyll concentrations have fallen with offshore concentrations being only slightly higher than those recorded in the 1960s. The concentrations in inshore waters were still relatively high and some high values were recorded. These values are much higher than 21 μg/L recorded by Talling (1966) in the Nyanza Gulf and 78 μg/L recorded by Ochumba and Kibaara (1989) during algal blooms in the Kenyan side of the lake. This increase in algal biomass is coupled with an increase in nutrient enrichment as recorded by Hecky et al. (2010) and Cornelissen et al. (2014).

2.3 Phytoplankton

The first comprehensive algal studies were carried out in the 1950s and 1960s, and reported a predominance of large diatoms particularly from the genera *Melosira* spp. (now called *Aulacoseira* spp.), *Stephanodiscus* spp. and *Nitzschia* spp. (Talling 1966). A 1960–1961 study in the offshore waters of the lake showed that diatoms increased in numerical abundance during periods of isothermal mixing of the whole water column (Talling 1966). Cyanobacteria on the other hand dominated the epilimnion during thermal stratification, while *Ceratium brachycerus* (a dinoflagellate) showed erratic variation. Green algae however remained sparse throughout the season. According to Verschuren et al. (2002), Lake Victoria was ecologically stable between about 1820 and 1940, with *Cyclostephanos* spp. and *Aulacoseira* spp. making up a large proportion of the present diatoms (80% and 15%, respectively) and *Nitzschia acicularis.* Stager et al. (2009) reported in Ugandan and Kenyan waters of Lake Victoria a transition from *Aulacoseira*-dominated planktonic assemblages to those dominated by long *Nitzschia* spp., from the mid-1970s to mid-1980s and 1940s to early 1950s respectively.

The algal community has greatly changed over the years and this has been attributed to the modification of the water chemistry and physical environment (Akiyama et al. 1977; Hecky 1993; Hecky et al. 1996, 2010; Lehman et al. 1998; Lung'ayia et al. 2000; Kling et al. 2001; Mugidde 2001). The *Aulacoseira* spp. (*Melosira* spp.) and *Cyclostephanos* spp. that made up 70–99% of the diatom biomass in the lake have been replaced by *Nitzschia* spp. during the 1990s (Kling et al. 2001).

Analysis of phytoplankton samples carried out during the period 2000–2004 revealed some similarities and differences with the situation observed in previous years. *Microcystis* spp., *Anabaena* spp., *Lyngybya* spp., *Merismopedia* spp., *Aphanocapsa* spp., *Nitzschia* spp. that were recorded by Talling (1987), Komarek and Kling (1991), and Akiyama et al. (1977) were also recorded during the surveys that were conducted from 2000 to 2004. Some species like *Surirella* spp., *Cymatopleura* spp., *Rhizosolenia* spp. and *Melosira (Aulacoseira*) spp. that were recorded by Talling (1987) were either not recorded or rarely encountered during 2000–2004 studies in the Tanzanian part of the lake (Mbonde et al. 2004). Quite a large number of *Anabaena* spp. and *Microcystis* spp. were observed reaching high values of 2.3×10^7 and 1.3×10^6 cells/L, respectively (Mbonde et al. 2004).

Reports show that *Aulacoseira* (*Melosira*) spp. and *Cyclostephanos* spp. that made up 70–99% of the diatom biomass have now been replaced by *Nitzschia* (Kling et al. 2001). The thinly silicified *Nitzschia acicularis* comprises about 94% of the total diatom abundance, while in the whole phytoplankton community, Cyanobacteria dominate lake-wide, especially during November–January (Kling et al. 2001; Mbonde et al. 2004). The species shift is interpreted as evidence of silicon limitation due to the increased diatom growth. This reduction concurred with the increased occurrence of a massive cyanobacterial blooms. Phytoplankton biomass evaluated as chlorophyll-*a* or as biovolume has increased six-fold to values ranging from 2.5 to 660.0 µg/L (Kling et al. 2001).

2.4 Physical Variables (Dissolved Oxygen Levels, Water Transparency)

Several studies on the limnology of the lake have indicated two major environmental regimes of alternating wet and dry seasons (Worthington 1930; Fish 1952, 1957; Newell 1960; Talling 1957, 1966; Akiyama et al. 1977; Melack 1979; Ochumba and Kibaara 1989). Dissolved oxygen levels could be tolerable for a number of species down the lake up to 50 m deep and fish could be caught at such depths (Kudhongania and Cordone 1974). Thermal stratification and mixing in the lake are the major physical properties known to control changes in the chemical and biological characteristics of the lake (Talling and Talling 1965; Talling 1969; Beadle 1981; Talling and Lemoalle 1998; Hecky et al. 1994; Mugidde 2001; Gichuki 2003).

Surface water during the period 1960–1961 was always near saturation with atmospheric oxygen (94–100%), except during mixing (90%) in July. Low dissolved oxygen conditions were only recorded below 55 m (less than 0.7 mg/L) and complete de-oxygenation (below 0.1 mg/L) (Talling 1966). These environmental changes in the lake have been attributed to increased anthropogenic activities due to population increase. Of importance is the intensification of land use and increased agricultural run-off of nutrients into the lake (Lowe-McConnell 1992). The levels of urban and industrial pollution are also increasing in the lake townships of Mwanza, Bukoba and Musoma (Mgaya 2005). Agricultural expansion has led to the removal of riparian vegetation that acted as a natural filter, thus aggravating the nutrient-rich status of the lake. In addition to increased anthropogenic activities, several papers have found evidence of climatic variability contributing to the low DO levels in the 1980s (Hecky et al. 2010; van Rijssel et al. 2016a).

It has been found by Van Rijssel et al. (2016a) that during periods of severe eutrophication and temperature increase in the 1980s, reduced wind speeds coincided with reduced DO levels and a decrease in both water temperature and transparency. They hypothesized that wind speed drives vertical mixing and thereby modifies DO levels in the lake. This hypothesis is supported by the increase of DO levels in the Mwanza Gulf during the 2000s after an increase of wind speed to speeds higher than recorded in the past 40 years. More comprehensive lake-wide observations are given by Sitoki et al. (2010) who observed relatively more rapid rise in temperature of the deeper waters which has weakened thermal gradients in the water column and reduced the intensity of stratification, which in turn has decreased the extent of anoxia in deeper waters. This has resulted into diminishing differences between oxygen concentrations in the surface layer (0–5 m depth) and in deep water (> 40 m) during the stratified period since 2001. Further, they observed an increase in Secchi disc visibility, indicating a reduced severity of algal blooms than previous surveys indicated.

2.5 Zooplankton

The zooplankton community of Lake Victoria comprises three groups i.e., the rotifers, cladocerans and copepods (Akiyama et al. 1977; Mavuti and Litterick 1991; Mwebaza-Ndawula 1994; Waya 2003, 2004). Prior to the introduction of *L. niloticus* the zooplankton community of Lake Victoria used to be dominated by cyclopoid copepods in terms of abundance and biomass (Akiyama et al. 1977; Mavuti and Litterick 1991; Mwebaza-Ndawula 1994; Branstrator et al. 1996) at the inshore research stations, but at the open water stations the diaptomids were equal or even dominant over cyclopoid copepods (Rzóska 1957). This differs from the work of Worthington (1930) who reported calanoid copepods to be dominant, and the presence of cladocerans in large amounts.

The composition of zooplankton species over the years has shown some changes (abundance and diversity) but the community structure still comprises the three groups – the rotifers and two subclasses of the Crustacea, the Cladocera and Copepoda (Waya 2003, 2004; Waya and Chande 2004; Chande et al. 2004; Waya et al. 2014, 2017). The factors regulating the density and production of zooplankton have been identified as temperature, food and predation (Herzig 1994; Hart et al. 1995). Currently food availability and predation, among others, seem to be important factors affecting density and biomass in Lake Victoria (Waya et al. 2014, 2017). The Copepoda population comprises nine species; *Thermodiaptomus galeboides, Eucyclops* spp., *Mesocyclops* spp., *Thermocyclops emini, Thermocyclops incisus, Thermocyclops neglectus, Tropocyclops confinnis,* and *Tropocyclops tenellus.*

Cladocera is represented by eight species: *Alona* spp., *Bosmina longirostris, Ceriodaphnia cornuta, Chydorid* spp., *Daphnia lumhortzi* (Helm.), *Daphnia barbata, Diaphanosoma excisum* and *Moina micrura.* Rotifera comprises 19 species, namely, *Ascomorpha* spp., *Asplanchna* spp., *Brachionus angularis, Brachionus calyciflorus, Brachionus caudatus, Brachionus falcatus, Brachionus forficula, Brachionus patulus, Brachionus leydig, Filinia longiseta, Filinia opoliensis, Keratella cochlearis, Keratella tropica, Keratella quadrata, Lecane bulla, Lecane inermas, Polyarthra* spp., *Synchaeta* spp. and *Trichocerca* spp. (Waya 2003, 2004; Chande et al. 2004; Waya and Mwambungu, 2004).

Apart from changes in diversity, the zooplankton abundance differs geographically. Zooplankton and rotifers are almost universally distributed in pelagic and littoral regions of Lake Victoria (Worthington 1931; Rzóska 1957; Akiyama et al. 1977; Mavuti and Litterick 1991; Mwebaza-Ndawula 1994; Waya 2003, 2004; Chande et al. 2004). Throughout the year, the zooplankton community is dominated by cyclopoid copepods in waters less than 30 m in depth, followed by the calanoids (Waya and Mwambungu 2004; Waya 2004; Waya et al. 2014, 2017).

2.6 Macroinvertebrates

Lake Victoria is home to a great variety of macroinvertebrate (>2 mm body length) taxa (e.g., oligochaetes, turbelarians, molluscs, insect larvae and crustaceans). Most of the taxa are associated with bottom sediments (macrobenthic) others with vegetation along the lakeshore and the littoral zones (macro-littoral invertebrates), while others are free swimming in the littoral or offshore zones (macro-pelagic invertebrates) (Ngupula and Kayanda 2010; Mwambungu 2004). Information on the abundance history of macroinvertebrates in Lake Victoria basin Tanzania is very scarce. It has been reported that since 1986 the abundance of macroinvertebrates such as *Chaoborus edulis*, the atyid prawn *Caridina nilotica*, oligochaetes, ostracods, molluscs, Chironomus, insect nymphs of Anisoptera and Ephemeroptera, have increased compared to the years before (Mbahinzireki 1992, 1994; Budeba 2003; Goudswaard et al. 2006). The eutrophication that has been reported throughout the lake seems to have provided favourable conditions for the flourishing of *C. nilotica* and other microinvertebrates in the lake (Hecky 1993; Mwebaza-Ndawula 1998; Mwebaza-Ndawula et al. 1999; Budeba 2003). A shift in macroinvertebrate abundance from an oligochaete- and insect-dominated community in 1984 to a community dominated by molluscs in 2008 was reported by Ngupula and Kayanda (2010).

2.7 Fish and Fisheries

Lake Victoria is among the most species rich freshwater ecosystems in Africa. In the mid-1950s, the lake had a diverse fish fauna comprising of 29 genera and about 550 or more species, most of them endemic (Graham 1929; Greenwood 1966; Witte et al. 2007a). Of these, the haplochromines comprised about 80% of the demersal fish stocks (Kudhongania and Cordone 1974; Greenwood 1974). The haplochromine group was made known to science in the nineteenth century (Hilgendorf 1888) as a sub-genus within the genus *Chromis*. Later on, Boulenger (1906) assigned the full generic status to *Haplochromis*. Much later, Greenwood classified the haplochromines of the Lake Victoria basin into 28 genera (Greenwood 1974, 1979, 1980). The haplochromines alone accounted for more than 500 species (Greenwood 1974; Witte et al. 1992; 2007b). These encompass mostly the discoveries of species in the southern part of Lake Victoria particularly where the HEST group (van Oijen 1981; Seehausen 1996; Seehausen et al. 1998) reported open water and rocky cichlids and Seehausen (1996) even estimated that over 200 more species await scientific discovery.

The haplochromines are widely distributed, occupying almost all the aquatic habitats within the basin; rocky shores, swamps, open water, satellite lakes and rivers. Up to 15 (sub) trophic groups (including 11 trophic groups) were identified mostly in the Mwanza Gulf (Witte and van Oijen 1990a, b). They included phytoplanktivores, detritivores, algal grazers, plant (higher plants) eaters, molluscivores, zooplanktivores, insectivores, piscivores, parasite eaters, paedophages and scale-eaters. Greenwood (1974) had earlier identified five trophic groups in the northern part of the lake basin. These included insectivores, piscivores, molluscivores, plant-eaters and scale-eaters. The haplochromines converted among others detritus, algae, zooplankton, insect larvae and molluscs into fish protein for consumption by higher trophic levels (Leveque, 1995). They were crucial in maintaining the ecosystem that supported other food fishes, as well as the high biodiversity associated with the lake basin (Worthington 1929; Greenwood 1965, 1966; Trewavas 1983).

Apart from haplochromine cichlids, other species were the tilapiine cichlid *Oreochromis esculentus* (Graham) and *Oreochromis variabilis* Boulenger, lungfish *Protopterus aethiopicus* (Burchell), Catfish *Clarias gariepinus* (Heckel) and *Bagrus docmak* (Forsskål). With haplochromines, all these species formed the backbone of the fishery (Graham 1929; Greenwood 1966; Ogari 1984). *Labeo victorianus* (Boulenger), *Synodontis* spp., *Brycinus* spp., *Barbus* spp., *Mormyrus* spp. were also found in the lake.

The introduction of gill nets in 1905 (Graham 1929), beach seines in the early 1920s and outboard motors in 1950s increased the fishing pressure (Garrod 1960). Lake-wide, the main target species was the *O. esculentus*, but other large growing fish species such as *O. variabilis*, *P. aethiopicus*, *C. gariepinus* and *B. docmak* (Forsskål) were also targeted for fishing (Graham 1929). Fishing pressure increased in the 1950s and 1960s resulting in decreases in catch per fishing effort, especially for the endemic tilapiine species (particularly *O. esculentus* and *O. variabilis)* and *L. victorianus* (Garrod 1960; Cadwalladr 1965; Fryer and Iles 1972; Fryer 1973; Ogutu-Ohwayo 1990a). Other species including *B. altianalis* (Boulenger), *Brycinus* spp. and *Mormyrus kannume* (Forsskål) were also becoming rare in the 1970s (Ogutu-Ohwayo 1990a).

Between 1954 and the early 1960s, Nile perch, a large piscivorous predator, was introduced on several occasions in the Ugandan and Kenyan parts of the lake to boost the fishery after the decline of indigenous fish species. In the same period, four tilapiines namely, *Tilapia zillii* (Gervais), *T. rendalli* (Boulenger), *O. leucostictus* (Trewavas) and *O. niloticus* (Trewavas), were also introduced into the lake to support the fishery (Welcomme 1988).

The former was introduced deliberately to create a recreational fishery and to convert the large biomass of the indigenous small bony haplochromine cichlids that were regarded as “trash fish” in the fauna (Graham 1929) into a less productive but more valuable commodity (Fryer 1960; Anderson 1961; Welcomme 1988; Pringle 2005). Nile perch spread rapidly across the Lake and by 1961 was reported in Mwanza, Tanzania, over 300 km from the sites of introduction. However, during the first 25 years following its introduction, Nile perch catches were insignificant. By 1972–1975 it was caught all over the lake as large adults (Kudhongania and Cordone 1974; Pringle 2005; Goudswaard et al. 2008). In addition, the introduction was aimed at managing the fishery, by permitting an extension of the fishing grounds into the deeper offshore waters and the use of a wider variety of gear for exploitation. This was meant to release fishing pressure on *Oreochromis* spp. whose habitat was within the shallow inshore areas of the lake (Anderson 1961).

In the 1980s, Nile perch increased suddenly in Lake Victoria and concomitantly, stocks of many other fish species declined in several areas of the lake (Hughes 1983; Ogutu-Ohwayo 1990a; Goudswaard et al. 2008). About 200 cichlid species were estimated to have vanished (Witte et al. 1992); the inventory had been made just in time to comprehend the extent of the disaster.

Nile perch has a preference for haplochromines (Ogari 1984; Katunzi et al. 2006) and it is suggested that the predatory Nile perch was partly responsible for the extinction of these fishes. Simultaneously, increases of the cyprinid *R. argentea* (Pellegrin), locally called dagaa, the shrimp *Caridina nilotica* (Roux) and other invertebrates such as molluscs and shrimps were noted (Kaufman 1992; Witte et al. 1992; Wanink 1999; Goudswaard et al. 2006). At about the same time the eutrophication in the lake increased strongly, causing algal blooms, decrease in levels of dissolved oxygen and water transparency. The eutrophication inflicted decreased water transparency is also likely to have contributed to the haplochromine biodiversity loss (Seehausen et al. 1997a). Furthermore, the mate choice of Lake Victoria cichlids is based on male colouration and they show strong assortative mating, which likely results in sexual isolation. As the decrease in water transparency hampered differentiation of both colours and colour vision, the mechanism of reproductive isolation gets blocked leading to hybridization (Seehausen et al. 1997a).

During the 1990s, Nile perch stocks declined, likely due to intensive fishing (Pitcher and Bundy 1995; Mkumbo et al. 2007; Kayanda et al. 2009) and eutrophication and the resulting hypoxia/anoxia (Kolding et al. 2008; Downing et al. 2014; van Zwieten et al. 2015). Concurrently, population of some haplochromine species mainly detritivores and zooplanktivores recovered in the Mwanza Gulf (Seehausen et al. 1997b; Witte et al. 2007a, b; Kishe-Machumu et al. 2015) and other areas of the lake (Balirwa et al. 2003). Of these two trophic groups, only a few species recovered, some of which are now even more abundant than in the past (Kishe-Machumu et al. 2015). The dominant species seem to have expanded the range of their diet types including macroinvertebrates, shrimps, molluscs and small fishes (van Oijen et al. 1996; Katunzi et al. 2003; Kishe-Machumu et al. 2008; van Rijssel et al. 2015; Kishe-Machumu et al. 2017; van Rijssel et al. 2016b) and of habitats considerably (Kishe-Machumu et al. 2015). These changes possibly resulted in a loss of specialisation and ecological segregation.

Moreover, morphological adaptations to the changed environment have been observed in some resurgent species (Witte et al. 2008; van der Meer et al. 2012; van Rijssel and Witte 2013; van Rijssel et al. 2015; van Rijssel et al. 2016a). For example, in the Mwanza Gulf of Lake Victoria, a site where haplochromines have been monitored by the Haplochromis Ecology Survey Team (HEST) and other projects, a strong increase in gill surface, a change in retina structure and changes in the feeding apparatus, size differences of intestines, which seem to be in response to the decreased oxygen concentrations, the changes in light conditions, the changes in diet (Witte et al. 2005, 2008; Kishe-Machumu et al. 2008; Kishe-Machumu et al. 2012) and low wind speeds inflicted by climatic variability (van Rijssel et al. 2016a). These changes have occurred in a time span of twenty years, or about as many generations.

2.8 Small Water Bodies

Small water bodies, which include satellite lakes, rivers, ponds, dams and floodplains in the catchment have been singled out as important faunal reservoirs and refugia for Lake Victoria endangered species (Maithya and Jembe 1998; Mwanja et al. 2001; Katunzi 2003). Fish communities of most of the satellite lakes are composed of native species, which are now threatened in the main lake (Katunzi et al. 2010). Significant populations of the two native tilapiine cichlids *O. esculentus* and *O. variabilis* remain in the satellite lakes although these two species no longer occur in the main lake in substantial quantities. These species were the most important target species in the past (Fryer and Iles 1972). The haplochromine cichlids are found in all lakes and dominated the catch (TAFIRI, 2002–2004). These lakes are important to the economy of the riparian communities, and may provide faunal reservoir for Lake Victoria endangered species. Furthermore, they provide micro-habitats for the breeding and feeding of fish species (Katunzi 2005).

Minor/satellite lakes, unlike Lake Victoria are Nile perch free and the structural barriers around the lakes and low oxygen regimes associated with them have hampered invasion by the perch. This has kept these areas intact with a balanced food web. Common to most of these lakes are wetland covers, which play a very important role in regulating and controlling the activities in these water masses (Carter 1955). For instance, the interwoven thick mass of macrophytes does not provide easy access to these lakes for the resource exploiters (e.g. local fisherfolk).

Studies in satellite lakes started in 1997. There are no time series observations made on these aquatic systems over the past years. However, several studies have shed light on the importance of these habitats (Katunzi 2003; Lyimo and Sekadende 2003; Katunzi and Kishe 2004).

A number of aquatic habitats in the basin include minor lakes e.g., Burigi, Ikimba and Malimbe), rivers (Kagera, Mara, Simiyu, Rubana, Suguti and Mori), and associated ox-bow lakes e.g., Kirumi (Fig. 2.1). These constitute a large assemblage of water bodies that harbour biodiversity and are of interest to scientists and riparian communities. Such extensive minor waters support the communities and are essential to the health, welfare and economy of the local population (Dugan 1990; Stuart 1990).

Satellite lakes are important to the economy of riparian communities and act as refugia for endangered fish species in the main lake. Therefore, effort should be made to employ management measures for conservation and sustainable utilization of satellite lake resources. Also, effort should be made to reduce nutrients load in the lakes and their catchments, which threaten their ecology. There is a need to strengthen community management units (CMUs) so that through these units, the community can participate fully in the whole process of conservation including decision-making. Satellite lakes also act as refugia for endangered plankton species.

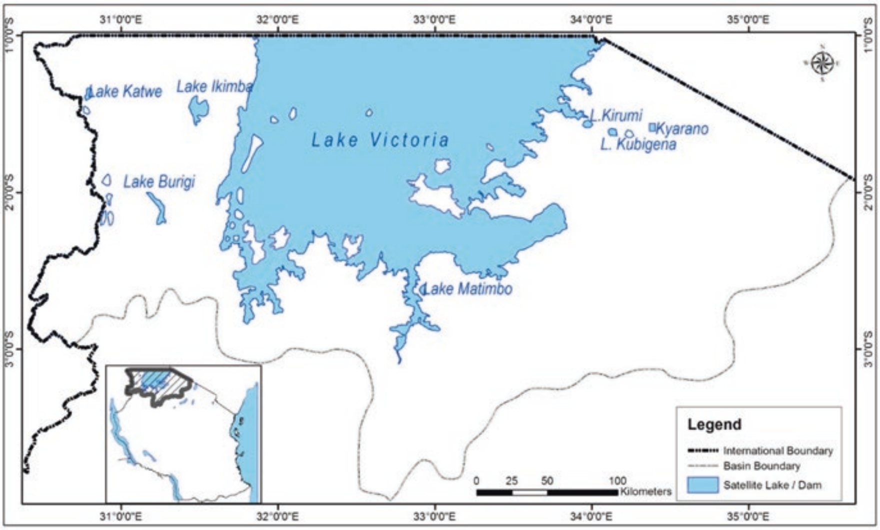

Fig. 2.1 Some of the studied satellite lakes around Lake Victoria (Source: TAFIRI/EWAG Report 2016)

2.9 Aquaculture

Aquaculture practice in the lake region is still at its infancy. A baseline study conducted by Bwathondi et al. (1998) on the western side of the lake indicated that aquaculture was acceptable in the region due to the reliability of rains, which ensures availability of adequate quantities of water. The most favoured fish species for culture were *O. niloticus* and *C. gariepinus*. Farmers were feeding fish with food leftovers (*matoke* and *ugali*) and crop leaves (cassava, yams, bananas, potatoes etc.). A total of 50 fishponds having a pond size range of 100 m^2 to 500 m^2 with the majority less than 200 m^2 were recorded. Fish species cultured were *O. niloticus, C. gariepinus, P. aethiopicus, Tilapia* spp. and *O. leucostictus.*

Generally, aquaculture production in the lake zone is mainly subsistence, non-market oriented, and is dominated by small-scale farmers (Bwathondi and Mahika, 1997). The lack of large-scale investment has led to low production and productivity. Recent endeavours include a military owned tilapia cage farm on Lake Victoria. Aquaculture production has increased to about 4000 tonnes per year, with Nile tilapia contributing about a third of this quantity.

2.10 Socio-economics

The importance of socioeconomic studies in Lake Victoria came into being after the realization of changes in various socioeconomic, environmental and biological indicators like population pressure, level of investments in the fisheries, socioeconomic activities and general decline of commercial fish stocks and fish stock diversity in the basin which resulted into changes in fisheries resources, land use patterns, water quality, biodiversity and wetland resources. In this regard, the socioeconomic research aimed at providing data and information for sustainable management and better utilization of aquatic resources in order to alleviate poverty amongst the communities, create wealth and sustain the resources for the present and future generations.

In view of this, socio-economic studies focused on two areas namely;

- Sustainable management of aquatic resources with greater community participation.
- The improvement of livelihoods of communities dependent on aquatic resources through better management of resources, fish farming, fish and other fish product marketing and development projects.

Human activities on the Lake Victoria basin have a considerable impact on the sustainable exploitation of the resources. While in the past, more emphasis was placed on natural science research; this did not adequately address human related problems. The involvement of IUCN, LVFRP I & II, LVEMP I & II and IFMP projects in undertaking socio-economic studies in the Tanzanian part of the lake, and especially the LVEMP whose principal aim was to involve the communities in management and conservation, brought more recognition of its importance in resolving some human impacts on exploitation and the wise use of the resources.

Since 1997, research activities on Lake Victoria have been driven by donor agencies such as the World Bank, European Union (EU), International Union for Conservation of Nature (IUCN), and The Swedish International Development Cooperation Agency – Department for Research Cooperation (Sida-SAREC). Other studies were conducted under UNDP/FAO/IFIP and International Development Research Centre (IDRC) sponsorship in the late and early 1990s. The above-named projects also funded socio-economic studies as outlined below and documented in Medard et al. (2002) and Medard (2003).

2.10.1 Lake Victoria Fisheries Research Project (LVFRP) Phase II

The project addressed issues related to:

Fish Marketing Study (1999)
This survey generated a comprehensive fish marketing data for the entire region of the lake. The survey concentrated on consumers, traders/processors serving local markets and industrial processors serving mainly international markets and fishers.

The section that dealt with consumers identified consumption habits, purchasing patterns and consumer preferences in relation to the fish products. The survey discovered that the region's most popular fish was tilapia *O. niloticus* preferred by 70% of consumers. The region's least favoured fish was the dagaa (*R. argentea*).

The study generated an understanding of the nature of trading in terms of individual products, quantities and activities involved. The survey discovered that there were more female fish traders and processors than men (about 56% of those involved in the trade are women). These traders and processors got their fish directly from fishers. Trade in fish species other than the Nile perch, tilapia and dagaa was negligible. It was observed that fish sales changed throughout the year. Fish sales improved just before farm harvests when granaries were empty and consumers had an alternative food supply other than fish.

The study also generated information on fish export marketing channels, factory supply sources, volumes and capacity, product formats and destination markets. It was observed that the majority of factories started operating in 1990. These factories got their fish supply from agents with whom they had long-standing relationships. A number of these factories obtained their fish supplies directly from fishers. The fish price as at that time was reported to be US$ 0.87 a kilo. This was the lowest regional price. There were eight processing factories in Tanzania with a total capacity of 402 tonnes of whole fish daily. These factories operated at 62% of their capacity during the survey period. The predominant fish products included chilled fish and frozen fillets. These were sold mainly in Europe, the Far East and the Middle East. The country's value of exports was the highest in the region at US$ 103 million.

The Co-management Survey (1999–2000)

This survey generated information on:

- Difficulties and impractical aspects inherent in implementing state-based regulations via a top-down management strategy;
- Prevalence of community-based institutions that either seek to regulate the fishery or have the potential to be used to regulate it;
- Ways in which community-based regulatory and monitoring systems may be established and how these fair over time; and
- Roles for the Fisheries Development Division, industrial fish processors and other stakeholders; it also came up with a well-founded policy suggestion for the establishment of a co-management framework to manage the fisheries of the lake.

The survey observed that the state-based centralised management systems on Lake Victoria suffered shortcomings such as under-staffing, under-funding, bureaucracy and corruption, among others. It also observed that the initiatives of Beach Management Units (BMUs) were external to the local communities' institutional set-up and an extension of the already bureaucratic Fisheries Development Division. However, based on the historical characteristics of local communities such external institutions are absorbed in social structures and cultural life such that they become socialised. There also exist local institutional initiatives, which have been very successful due to recognition and support by the state. This is thought to be a very useful ingredient for the success of any institutional framework needed for the management of the lake's fish resources.

Survey of Lake Victoria Fishers (2001)
The survey of fishers generated information on the relationships affecting supply flows of raw materials into the market and the characteristics of fishing activities and their effects on fish quality and distribution. It was observed that all the fishers were male although there were a few female boat owners. Gillnets are the most commonly used fishing gear. Two thirds of the fishers in the lake target the Nile perch followed by dagaa and tilapia. Fishers had agreements where they sell their catches to factories in exchange for loans and/or credits.

The survey concluded, among others, that while the fishery provides employment for many of the region's males, it is somewhat different from many other fishing cultures in that male spouses are rarely engaged in fisheries related activities and that fishing is practised alongside agriculture. The very large biological changes that have affected the lake are reflected in the typically low diversity of the targeted species. This is not only due to low species diversity within the lake, however, but also due to high regional and international demand for the lake's dominant species.

Participatory Rural Appraisals (PRA) in Five Beach Studies (2-Tanzania, 2-Uganda and 1-Kenya) (2001)
This was part of the wider co-management survey. But specifically, it addressed the shortcomings that were encountered and anticipated in the co-management survey, namely, exploring to some degree of details the dynamics of community-based institutions. The study was called participatory because it solely used PRA techniques to study the institutional dynamics at the local level. In particular, the study addressed the following objectives:

- Identification of community institutions which either seek to directly regulate access to or ownership of fisheries resources or those institutions which could be used for these purposes;
- Understand whether or not community-based institutions are able to support externally introduced regulations such as state-sourced suggestions;
- Understand the kinds of benefits that communities require in order to adopt and/or develop regulatory institutions. Perceptions of these benefits and the regulations that they support will need to be understood if community-based regulations are to form a component in a co-management framework for Lake Victoria;
- Understand what factors contribute to the survival of community-based institutions; and
- Identify how extension services can be delivered to communities, the form these should take and the types of services that such communities may require.

This survey generated information on taboos and culture of the Sukuma community surrounding the lake, their resource output overtime and indigenous knowledge they used in managing their resources, among others. In general, the survey revealed that there are a number of local-level institutions, which could potentially play an important role in the management of the fishery. There are numerous women organisations at this level whose lives depend directly and indirectly on the fisheries. New initiatives such as the BMUs had not made any impact on the lives of the local communities.

An Assessment of the Nutritional Status of Fishing and Farming Communities in the Lake Victoria Basin, Tanzania (2002)
This survey observed that childhood malnutrition is a major problem for Tanzanian lake zone communities. Forty-one percent (218) of the children measured were chronically malnourished, 5% (27) were acutely malnourished and 21.4% (114) suffered from acute and chronic malnutrition combined (n = 531). Although cultural beliefs still have a role to play in how malnutrition and its management are perceived, an emphasis on health education is important to reduce the discrepancies between knowledge and practices arising from inadequate resources. It is this discrepancy that affects the type of food crops consumed, how they are distributed within the household, the extent to which they are affected by gender biases and the relevance of culture.

2.10.2 Implementation of Fisheries Management Plan (IFMP/LVFO) (2002–2008)

This project's overall objective was to contribute to the sustainable economic growth, resource use and development in the Lake Victoria Basin. The project intended to:

- Achieve an effective coordination of the implementation of the Lake Victoria Fisheries Management Plan;
- Strengthen communities' abilities to co-manage the fisheries;
- Improve fisheries infrastructure;
- Establish a sustainable monitoring, control and surveillance system as well as resource and socio-economic monitoring systems; and
- Strengthen the LVFO Secretariat as a coordination centre of Fisheries Institutions.

The project has set itself quite a challenging purpose aligned to the wider development goals for the partner states as well as the millennium goals. Four indicators were set to show that the project was making an impact within the riparian communities. These indicators included:

- economic growth;
- poverty reduction;
- empowerment of women; and
- food security

The macro-economic indicators relating to economic growth included:

- increasing foreign exchange earnings from fish exports; and
- an increase in the total value of the catch from Lake Victoria fisheries.

The research component provided information on all of these indicators except for foreign exchange earnings from fish exports, which is provided by the fish export companies. The first set of microeconomic indicators was expected to be generated from the establishment of an effective lake-wide network of BMUs as well as studies that should have been undertaken to monitor them.

On the empowerment of women and food security, the information generated by the socio-economic baseline survey provided a status of the indicators. In addition to this, the information generated by Catch Assessment Survey (CAS) was expected to provide information on food security as this has a bearing on total fish catch for domestic markets that CAS collects.

This survey focused on:

- describing and analysing the structure, institutional framework and the performance of BMUs in the co-management framework in Lake Victoria;
- creating awareness to the fishing communities/local government authorities at the village, ward and district administration;
- forming/reforming new BMUs in places where they do not exist;
- determining the problems affecting the performance of BMUs;
- determining the factors which could lead to the success and sustainability of BMUs; and
- recommending intervention measures for improving BMU performance in Tanzania.

A number of problems were identified to be faced by the BMUs; these included among others, lack of legal power, lack of finance and incentives, poor leadership, lack of feedback mechanisms, unacceptability of BMUs in the community, lack of working facilities and lack of knowledge about fisheries regulations and policies. The survey recommended that in order to make BMUs more effective: they should be given working facilities, an incentive package should be worked out, frequent seminars and trainings should be organised, BMUs should perform joint patrols at the ward level and the government provide legal backing, among others.

2.10.3 International Union for Conservation of Nature (IUCN): The Socio-economics of the Nile Perch Fishery (2001–2005)

The project aimed at contributing to sustainable and equitable use of Lake Victoria fisheries resources, through the improved understanding of social and economic trends and their recognition in policy and management decisions. The project addressed this by primarily strengthening the capacity of institutions to address emerging social and economic issues affecting the lake's fisheries and the livelihood of fishers. Project outputs were in four Key Results Areas:

1. *Key results area 1:* Improved information dissemination on Lake Victoria Fisheries;
2. *Key results area 2:* Improved capacity of resource user groups to participate in Lake Victoria management;
3. *Key results area 3:* Improved fisheries policy and implementation on Lake Victoria through the participation of BMUs;
4. *Key results area 4:* Efficient and transparent implementation process established in partnership with LVFO.

Cross Border Fishing and Fish Trading (2001)
This study assessed and documented the views of border fishing communities and their leaders on the challenges and opportunities for improved fisheries management at the international border areas. The study was undertaken in recognition of the complexity of involving communities in managing a mobile resource (fish) across international borders where people, unlike the managed resource, understand and try to comply with the political and legal responsibilities.

The aim of the assessment was to provide information to facilitate policy makers to:

- address the issues of conflict, authority and implementation of the law at border interfaces;
- incorporate community priorities into the design of management initiatives;
- adopt concepts of resource ownership, management and co-management.

The findings and recommendations of the study are documented in the Fisheries Management Series Volume 1 (Heck et al. 2004), and formed the basis of the mechanism for resolving cross-border conflict and BMU capacity building programmes.

Following some of the recommendations from the above study, the project also compiled an extract of the relevant rules and regulations governing Lake Victoria fisheries from each of the three countries. This was compiled in one brochure, produced in English and later translated into the three common languages spoken around the lake namely, Jaluo, Kiswahili and Luganda.

Rural User Groups in Fishing Communities (2002)
This study generated an understanding of the types of groups in existence, their activities and motivations, relationships with other groups, opportunities and constraints for their effective participation in Lake Victoria fisheries resources management. The study also assessed the resource user groups' managerial and technical capacities, financial resources and sustainable funding strategies.

The findings of this study are documented in Volume 3 of the Fisheries Management Series (Heck et al. 2004). Key findings include the fact that the groups demonstrated the ability to mobilise local resources to meet their localized needs and can therefore help improve the link between local action and national objectives. There was adequate social capital, creating opportunities for incorporating the groups to participate in the management of the fishery and socio-economic development. However, most of the groups faced serious challenges in realising their objectives. Notable among the challenges are:

- Inadequate technical, managerial and financial management skills and capacity, inadequate knowledge in fisheries conservation measures, fish preservation and value addition processes and marketing.
- Declining fish catches due to too many fishers and overcapacity of processors, use of illegal fishing methods and gear, migration of fishers, theft of fishing gear, lack of disaster warning and mitigation systems (insecurity of fishers on open waters), and threat of human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS).

2.10.4 Lake Victoria Environmental Management Project Phase I (LVEMP I) (1997–2005)

The socio-economic sub-component of LVEMP mainly aimed at:

- Compilation of national socio-economic research and dimensions on the Fisheries Sector of Lake Victoria (National).
- Community participation in the fishing industry from production to marketing: an overview of the factors influencing the involvement in the fishing industry of Lake Victoria, Tanzania.
- A report on the impact of fisheries on the resources along the shores of Lake Victoria.
- A study on communicable diseases, health and sanitation along the Lake Victoria fishing communities in Tanzania.
- Study on how to make BMUs more effective.

2.10.5 Lake Victoria Environmental Management Project Phase II (LVEMP II) (2009–2017)

The second phase of LVEMP has mainly focused on fisheries resource monitoring in which one hydroacoustic survey, four frame surveys, two catch assessment surveys were carried out on the main lake, two surveys on satellite lakes and several monitoring, control and surveillance (MCS) patrols. In terms of capacity building, fisheries laboratory, research and management institutions received support in equipment and training. In addition, it supported a number of fisheries related community driven projects in which BMUs were the final beneficiaries and eco-labelling initiatives.

2.11 Conclusion

On the basis of the foregoing background information on research activities in the lake during the last couple of decades, LVEMP I activities were designed with an intention to complement the existing initiatives but without duplicating any activities that were already being undertaken. To this end, it was clear from the outset that the LVEMP I would not undertake trawl and hydroacoustic surveys that were already being carried out by the two EU funded projects, namely, LVFRP and IFMP. The fundamental objective of the LVEMP I remained consistent with restoring a healthy, varied lake ecosystem that is inherently stable and that can support, in a sustainable way, many human activities in the catchment areas and on the lake itself.

The future research needs as far as aquaculture is concerned are identification of cage sites and their carrying capacity, feeding and broodstock. In socio-economics, there is a need to carry out economic valuation of the fisheries to determine its value so as to guide investment and sustainable exploitation of the resources, develop fish specific licensing and continue with resource monitoring surveys such as hydroacoustic, bottom trawls, CAS, frame surveys and gillnet to inform the management of the fisheries resources.

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Chapter 3
Environmental Changes in the Tanzanian Part of Lake Victoria

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Abstract Lake Victoria is known for its explosive speciation and recent time hybridization, which is highly mediated by deterioration of water quality. This chapter summarizes the knowledge on change of water quality and environment of southern part of Lake Victoria, Tanzania. It analyses rainfall, air temperature and water quality data spanning 30 years (1985 to 2015). It also investigates changes in physical-chemical data sampled during and after the Lake Victoria Environmental Management Project I (LVEMP I). The chapter reviews some of the significant water quality changes that have occurred for the past 50 years. The results indicate no significant changes in annual rainfall variability. Nevertheless, trends of air temperature showed no clear patterns for Mwanza and Musoma, but trends of minimum and maximum air temperature in Bukoba increased significantly at annual rates of 0.19 °C and 0.14 °C, respectively. Water level in Lake Victoria has also declined significantly at an annual rate of about 5.5 cm from 1965 to 2004. These findings suggest that lake levels are determined by evapotranspiration rather than rainfall. It was also found that anthropogenic stressors are more important in explaining nutrients loading while thermal stratification explains hypoxia and reduction in water mixing. It is concluded that the current blooms of harmful algae and excess biomass in Lake Victoria will continue unabated unless nutrient loading, anoxia and high rates of denitrification are curbed. Appropriate measures to improve land use management should therefore be taken, while deliberate

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dumping of industrial, municipal and agricultural wastes into the lake should be controlled.

3.1 Introduction

Lake Victoria is the largest lake by area in Africa and second largest freshwater lake in the world, second only to Lake Superior in North America (Hecky et al. 1994; Scheren et al. 2000). The lake is best known in the world for its faunal diversity, explosive speciation and recent time hybridization. The lake is extremely diverse and provides various ecosystem goods and services to over 30 million people who are estimated to either directly or indirectly depend on the lake for their sustenance. Lake Victoria supplies water for domestic and industrial consumption, agriculture and hydroelectricity production. It provides fish, which serves as a source of animal protein and income; an aesthetic value, which attracts tourists and other non-economic benefits; and a scientific value for academic and research purposes. However, these benefits are jeopardised by the current destructive human activities, such as unsustainable agriculture, urban development including unplanned and illegal settlements, overfishing, industrial development, and introduction of alien and invasive species (Hecky 1993; Msomphora 2005). Furthermore, the lake is a recipient of agrochemicals, domestic and industrial wastes, and mining effluents that are causing havoc to the lake's environment, thereby jeopardizing the provision of ecosystem goods and services to the riparian communities. It has been polluted such that it reached a 'tipping point' and went into a permanent eutrophication phase since early 1980s.

Some of the changes that caught attention of the scientific fraternity include prolonged anoxia in deep waters (Ochumba and Kibaara 1989; Mugidde 1993; Hecky et al. 1994), which resulted into periodic massive fish kills, during the cool dry season's mixing events (Akiyama et al. 1977; Hecky et al. 1994). Periodic anoxia condition in deep waters of the lake is however not an uncommon phenomenon. It was reported by several studies even before eutrophication of the lake could be ascertained (Worthington 1930; Talling 1966; Akiyama et al. 1977). Since then, the water quality of Lake Victoria has thus changed towards the negative extreme of the spectrum. The change in water quality has been associated with unsustainable human activities such as increasing agricultural activities, clearing of forests, pastoralization, and domestic and industrial effluents, and mining wastes (Hecky 1993; Msomphora 2005). These activities are cause for excessive nutrients input into, and the eutrophication of, Lake Victoria.

The lake is also facing the challenge of increasing algal blooms (Mugidde 1993), which have contributed to the 'new nuisance' and changing the odour of the lake water while rendering some parts of the lake unusable by affecting its aesthetic value. The occurrence of toxic algal blooms such as microcystin (Mbonde et al. 2004; Sekadende et al. 2005), and the introduction of non-native fish species such as Nile Perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*) and water hyacinth (*Eichhornia crassipes*) have also contributed to the dramatic shift of the ecological status of the lake's ecosystem. The prolonged deepwater anoxia has affected effective habitats with serious reduction of fish and invertebrates in the lake (Witte et al. 2005; Ngupula et al. 2012). For example, previous studies have documented the disappearance of hundreds of the trophically diverse haplochromine cichlids in Lake Victoria (Witte et al. 1992a, b), which resulted into an over simplified food web and eutrophication of the lake (Msomphora 2005; Kolding et al. 2008).

The continual tendency of water quality degradation in Lake Victoria became the focus of research, attracting scientists from various fields during the World Bank funded projects such as the Lake Victoria Environmental Management Project (LVEMP I) in late 1990s (see Chap. 1 of this volume). While there is a clear signature of the impacts of human activities on the deterioration of water quality and environmental degradation, Lake Victoria is also facing the challenges of climate change that are adding an extra layer of complexity to the changes. Previous studies have shown that historical trends in air temperature and rainfall vary across the lake on decadal timescales. Air temperature over the lake is increasing, wind speeds are decreasing, precipitation is becoming low and unpredictable while the lake level is experiencing a decreasing trend (Swenson and Wahr 2009). The ecology of the lake has also changed as a result of both eutrophication and exotic species introductions (Hecky et al. 2010). This chapter reviews previous studies to unmask ecological and water quality changes over time including recent time changes and provides recommendations for monitoring and management solutions.

3.2 Methods and Data Analysis

The physical and chemical data analysed in this chapter were collected under the Lake Victoria Environmental Management Project (LVEMP I & II). The water level data of the lake were gathered from Mwanza Water Supply and Sanitation Authority (MWAUWASA) archive. The archive contains water level from 1961 to 2004; however, only the data between 1966 and 2004 were used because the preceding years' data were of poor quality. Historical measurements of air temperature and rainfall were obtained from the Tanzania Meteorological Agency (TMA). The agency contains data since early 1980s to date. The TMA repository contains daily measurements of rainfall, minimum and maximum air temperature. However, only monthly and annual means of these variables are accessible at TMA. All data were checked for normality and homogeneity of variances using the Shapiro-Wilk and Levene's test before statistical tests could be conducted. The data failed to meet the assumptions of parametric tests, which assume equal variance, even after transformation. Therefore, the non-parametric alternatives were used.

Water level change in Lake Victoria was calculated using a non-parametric Mann-Kendall Trend test. Mann-Kendall test was used to detect trends because this statistical test is robust for noisy observations and has the ability to identify intra (seasonal) and inter-annual trends of data characterized with non–normality and heteroscedasticity. In order to assess the possible drivers of declining water level, the annual means of rainfall, minimum and maximum air temperature of selected sites, i.e. Bukoba, Mwanza and Musoma, were compared using a non–parametric Kruskal-Wallis test. Changes in air temperature over time were calculated using Mann-Kendall Trend test applied to time series. Two periods were identified for analysis. The first is the entire 1985 to 2004, a period of 20 years. The second is the most recent 11-year period between 2005 and 2015. Standard statistical significance tests were performed on all results. The analysis and plotting performed in this chapter were conducted using statistics and machine learning toolbox (version 10) in MATLAB version R2015a and EnvStats Package of R language and environment for statistical computing version 3.2.3 (Millard 2013).

3.3 Results

3.3.1 Air Temperature

Air temperatures of regions bordering Lake Victoria in Tanzania-Bukoba, Mwanza and Musoma vary across and contain significant departures from each other (Fig. 3.1). Mean maximum air temperature was significantly lower in Bukoba (mean ± SD = 26.01 ± 0.36 °C) than in Mwanza (28.42 ± 4.40 °C) and Musoma (28.71 ± 0.34 °C) respectively (Kruskal-Wallis, $W_{(2,92)} = 65.2$, $p < 0.001$). However, the mean maximum air temperature was not significantly different between Mwanza and Musoma ($p = 0.095$; Fig. 3.1a). Similarly, mean minimum air temperature was significantly lower in Bukoba (17.09 ± 0.92 °C) than Mwanza (17.60 ± 0.88 °C) and Musoma (17.86 ± 0.60 °C) ($W_{(2,95)} = 10.97$, $p = 0.004$; Fig. 3.1b). Mean annual minimum and maximum air temperature anomaly trends for Bukoba, Mwanza and Musoma since 1985 are presented in Figs. 3.2, 3.3 and 3.4, respectively. While the

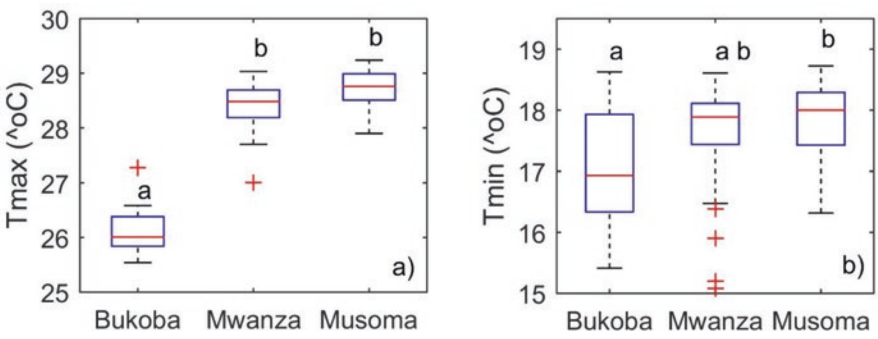

Fig. 3.1 Mean air temperature (**a**) maximum and (**b**) minimum for Bukoba, Mwanza and Musoma from 1985 to 2015

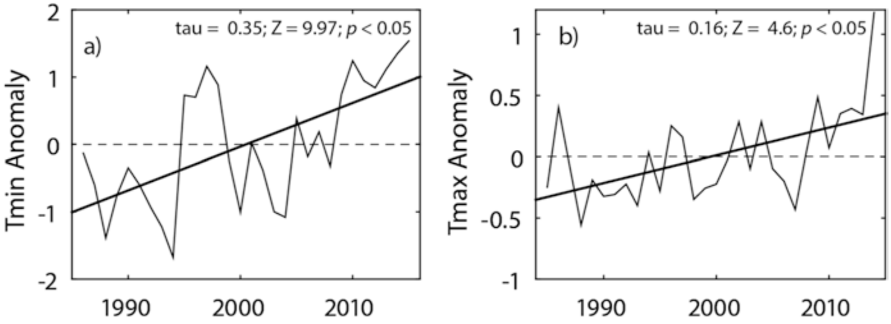

Fig. 3.2 Minimum (**a**) and maximum (**b**) air temperature anomaly for Bukoba for the period 1985 to 2015. Plain line = mean annual temperature anomaly, bold plain line = trend line and dotted line = historical mean anomaly

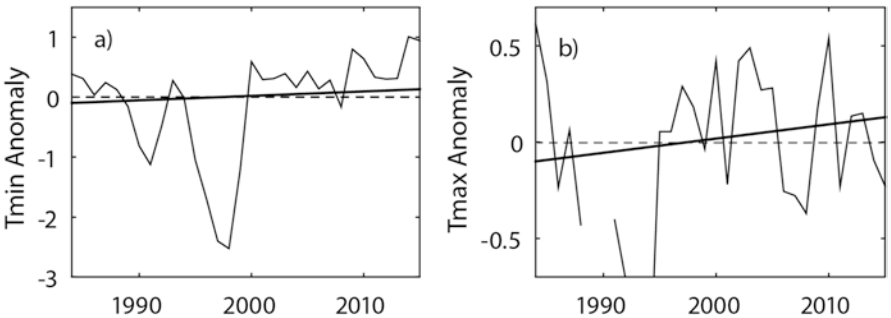

Fig. 3.3 Minimum (**a**) and maximum (**b**) air temperature anomaly for Mwanza for the period 1985 to 2015. Plain line = mean annual temperature anomaly, bold plain line = trend line and dotted line = historical mean anomaly

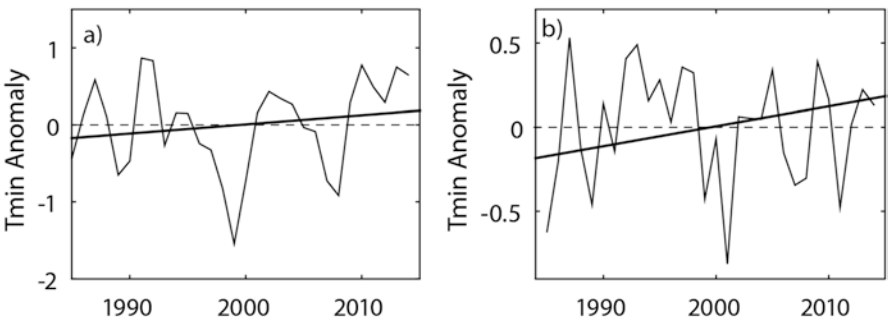

Fig. 3.4 Minimum (**a**) and maximum (**b**) air temperature anomaly for Musoma for the period 1985 to 2015. Plain line = mean annual temperature anomaly, bold plain line = trend line and dotted line = historical mean anomaly

Table 3.1 Summary statistics, trends and hottest years at the Bukoba site with data decomposed into 1986–2004 and 2005–2015 period

Period	Mean	tau	Z	p	Hottest years
1986–2015	17.09 ± 1.09	−0.02	−0.59	0.55	–
1986–2004	17.09 ± 1.13	−0.074	−1.71	0.08	1995, 1996, 1997, 1998, 2001
2005–2015	17.09 ± 1.00	0.14	2.19	0.028	2005, 2007, 2009,2010, 2011–2015

mean maximum and minimum air temperature anomaly for Mwanza (Fig. 3.2a, b) and Musoma (Fig. 3.3a, b) showed no clear variations over time, both maximum and minimum air temperature for Bukoba showed a significant positive increasing trend (Fig. 3.4a, b). While maximum temperature at Bukoba has increased at a rate of 0.14 °C per year between 1985 and 2015, the minimum air temperature increased at 0.19 °C per year for the same period. The average of the Bukoba station shows that in the period 2005–2015 there were more years with above mean minimum temperature compared to the 1986–2004 period (Table 3.1). This indicates a significant increasing trend in temperature for the period between 2005 and 2015 ($\tau = 0.14$, $Z = 2.19$, $p = 0.028$) compared to an insignificant temperature change during 1985–2004 ($\tau = -0.074$, $Z = -1.71$, $p = 0.08$).

3.3.2 *Rainfall*

The monthly mean distribution of rainfall in Bukoba, Mwanza and Musoma area are shown in Fig. 3.5. It indicates that the rainfall pattern within the lake region exhibits two seasons – a long rainy season (March – May) and a short rainy season (October – December) (also see Fig. 3.6a). Generally, monthly mean rainfall is higher during the long rainy season (March – May) for all selected sites around the lake. However, Bukoba has relatively higher rains than the rest of the sites, with the highest monthly mean rainfall of 344 mm in April (Fig. 3.6a). The year–to–year annual mean rainfall fluctuations over the past 30 years, which seem to correspond to El-Nino events, are presented in Fig. 3.6b. However, there has not been a clear overall increasing or decreasing trends in annual mean precipitation between 1985 and 2015 for the selected sites in the lake regions. The highest amounts of annual rainfall recorded for Bukoba, Mwanza and Musoma were 2544, 1530 and 1271 mm, which were recorded in 1994, 2014 and 2012, respectively. The minimum rainfall values were 1523, 671 and 616 mm for Bukoba, Mwanza and Musoma, which were recorded in 2000, 2000 and 1993 respectively (Fig. 3.6b). The mean annual rainfall was significantly different among the selected areas around Lake Victoria, Tanzania ($W_{(2,90)} = 66.68$, $p < 0.001$); where Bukoba received significantly highest annual rainfall of all sites (2005 mm, $p < 0.001$; Fig. 3.6c), followed by Mwanza (1140 mm) and lowest in Musoma (908 mm). The differences between mean annual rainfall between Mwanza and Musoma were also significant ($p = 0.021$; Fig. 3.6c).

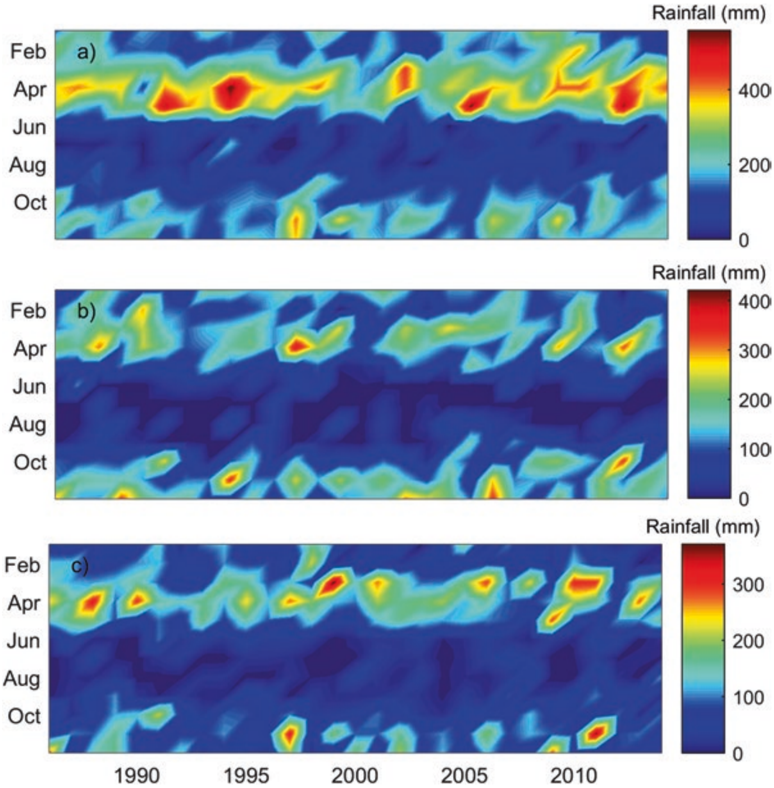

Fig. 3.5 Mean monthly rainfall for (**a**) Bukoba, (**b**) Mwanza, and (**c**) Musoma, determined from rainfall measurements recorded from 1985 to 2015 by the Tanzania Meteorological Agency (TMA)

3.3.3 Lake Water Level

Figure 3.7a–c show mean water level of Lake Victoria recorded at the Mwanza South station. It shows that Lake Victoria exhibits a peak water level during the period of May–June (9.00 m)—lagging the peak of the long rainfall season by one-to-two months; and reaches its minimum level in October (8.71 m), at the beginning of the short rainy season (Fig. 3.7a). The water levels in Lake Victoria have clearly exhibited inter-annual variability but with two major peaks, one in 1979 (9.55 m) and another in 1998 (9.37 m), and the lowest in 2004 (8.17 m) (Fig. 3.6b). An annual trend applied to the time series indicate a significant decreasing trend ($\tau = -0.46$; $Z = -14.93$; $p < 0.001$), which indicates that the lake water level is declining at a rate of about 4.6 mm per year since 1966, but with inter–annual variability (Fig. 3.7b). Moreover, the Hovmoller diagram indicates a decrease in extreme water level events over time. Extreme high-water levels occurred during 1969–1970, 1979/1980 and 1998 (Fig. 3.7c). These extreme water levels spanned throughout the years, which could be associated with the occurrence of El-Niño events.

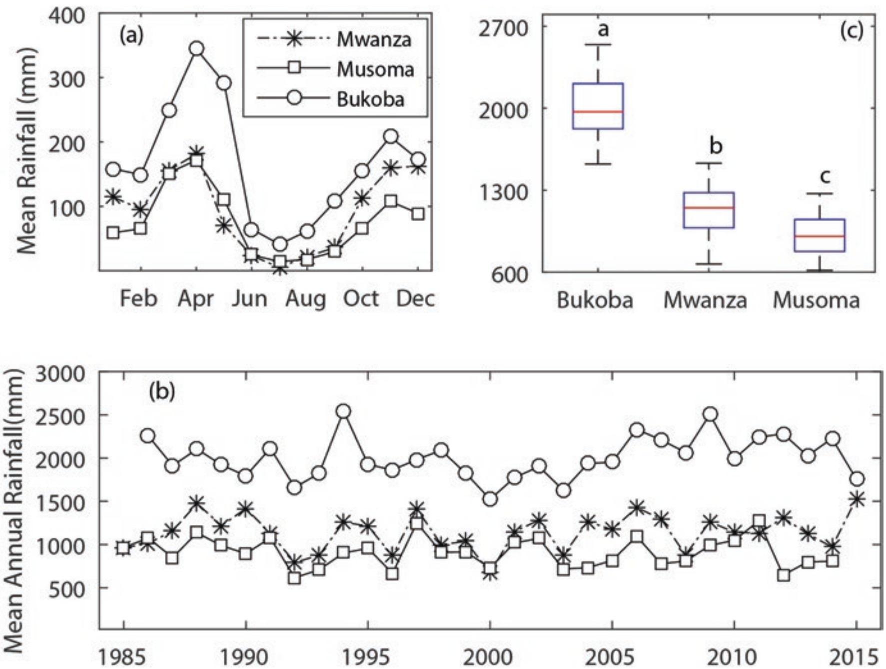

Fig. 3.6 (**a**) Mean monthly rainfall, (**b**) mean annual rainfall and (**c**) boxplot of annual rainfall for Bukoba, Mwanza and Musoma during 1985–2015

3.3.4 Water Transparency

Transparency in waters below 10 meters has increased from 1.06 ± 0.35 m in 2005 to 2.73 ± 1.30 m in 2014; while the values in waters deeper than 40 m were relatively higher in 2008 (4.52 ± 1.24 m) and lower in 2009 (3.31 ± 064 m) (Table 3.2). The spatial distribution of water transparency for the Tanzanian portion of Lake Victoria is illustrated in Fig. 3.8. It indicates that western and southern areas of the lake – Bukoba town and Mwanza city, have predominantly low water transparency, which can be attributed to urban pollution (Fig. 3.8). The areas with water transparency above 3 meters are located within the central and eastern sides of the lake.

3.3.5 Water Temperature

Water temperatures were relatively cooler in the water depth below 10 m except in 2009 when temperatures as high as 26.26 ± 0.82 °C were recorded. The water column temperatures for three consecutive years, 2007, 2008 and 2009 were relatively warmer than for 2005 and 2014 (Table 3.3). Nonetheless, temperatures in water depth above 40 m were lowest in 2014 (24.22 ± 0.21 °C) and warmer in 2009 (25.16 ± 0.33 °C).

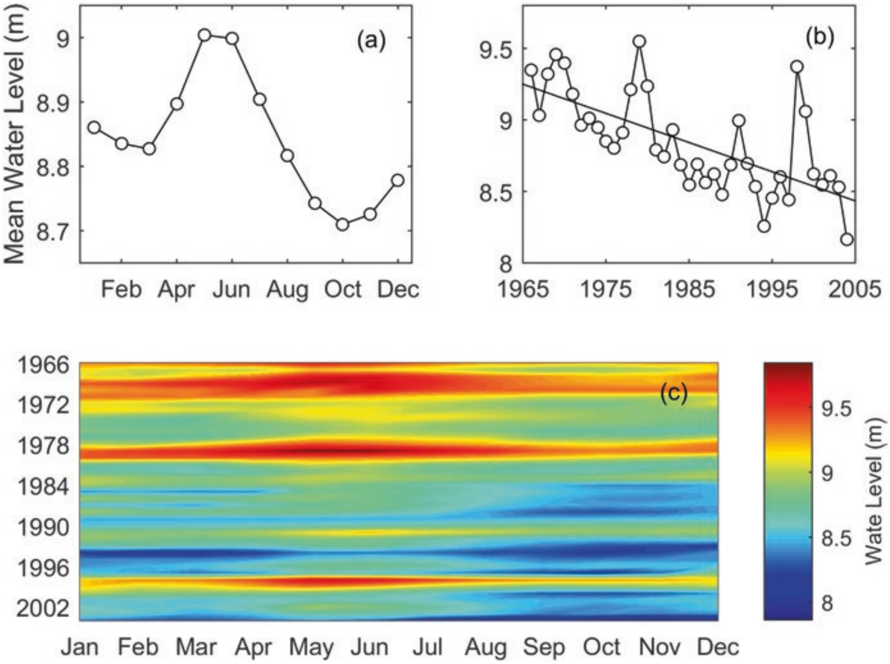

Fig. 3.7 Water levels measured at Mwanza South Port for the period 1965–2004

Table 3.2 Water transparency at different depth strata in Lake Victoria

Depth strata (m)	Transparency (m)					
	2005	2006	2007	2008	2009	2014
Below 10	1.06 ± 0.35	1.22 ± 0.23	2.84 ± 1.56	2.82 ± 1.54	2.18 ± 1.17	2.73 ± 1.30
10 to 20	1.68 ± 0.56	1.56 ± 0.49	3.23 ± 1.50	3.24 ± 1.48	2.58 ± 1.05	2.99 ± 1.02
20 to 40	2.71 ± 0.70	3.00 ± 0.72	3.80 ± 1.34	3.78 ± 1.35	2.98 ± 0.88	3.37 ± 1.02
Above 40	3.61 ± 0.74	3.69 ± 0.41	4.44 ± 1.12	4.52 ± 1.24	3.31 ± 0.64	3.75 ± 0.96

3.3.6 Dissolved Oxygen

Dissolved oxygen was higher in waters below 10 m deep almost consecutively from 6.34 ± 2.31 mg/L to 7.69 ± 0.74 mg/L in 2005 and 2014 respectively but with a relatively large value recorded in 2007 (7.92 ± 4.20 mg/L). With the exception of 2007 and 2009 where the DO concentrations were evenly distributed throughout the water column, the values for DO in waters deeper than 40 m was 4.36 ± 0.71 mg/L and 4.95 ± 1.48 mg/L in 2005 and 2014 respectively (Table 3.4).

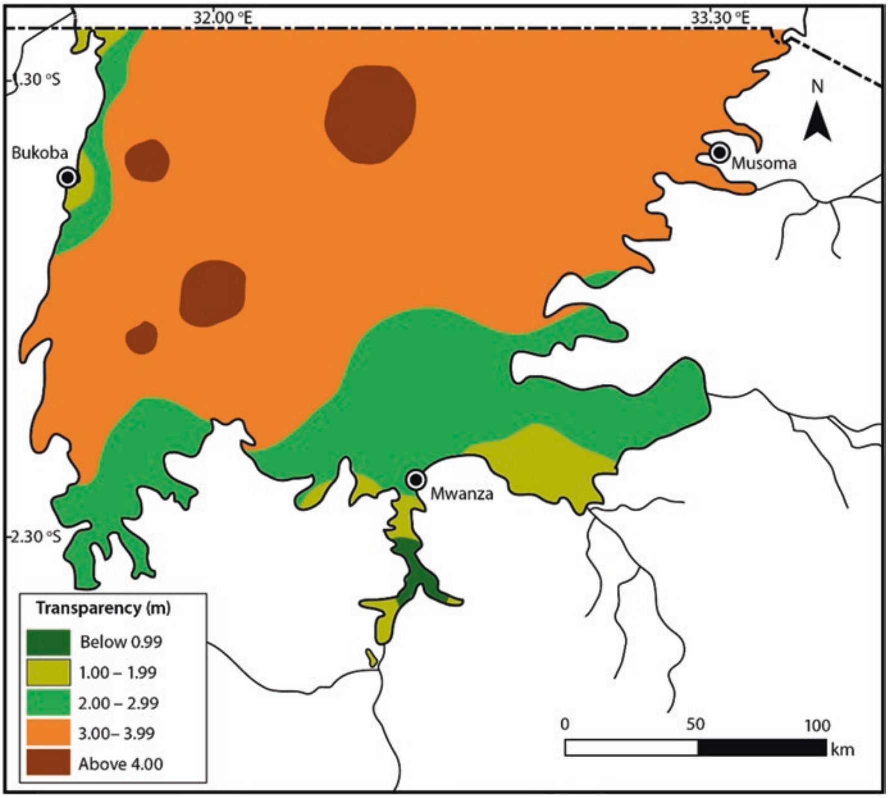

Fig. 3.8 Spatial distribution of Secchi depth transparency in the Tanzanian part of Lake Victoria between 2000 and 2005

Table 3.3 Mean temperature distribution at different depth strata in Lake Victoria

Depth strata (m)	Temperature (°C)					
	2005	2006	2007	2008	2009	2014
Below 10	24.22 ± 3.93	25.31 ± 0.83	24.54 ± 0.85	25.45 ± 0.76	26.26 ± 0.82	25.16 ± 0.48
10 to 20	25.13 ± 1.08	25.74 ± 0.74	25.28 ± 0.66	25.23 ± 0.68	25.97 ± 0.96	24.83 ± 0.31
20 to 40	24.99 ± 0.81	25.43 ± 0.76	25.01 ± 0.44	25.01 ± 0.56	25.65 ± 0.51	24.53 ± 027
Above 40	24.80 ± 0.68	25.23 ± 0.44	24.81 ± 0.24	24.73 ± 0.32	25.16 ± 0.33	24.22 ± 0.21

Table 3.4 Dissolved oxygen at different depth strata in Lake Victoria

Depth strata (m)	Dissolved oxygen (mg/L)					
	2005	2006	2007	2008	2009	2014
Below 10	6.34 ± 2.31	7.75 ± 1.66	7.92 ± 4.20	7.45 ± 0.98	7.84 ± 1.13	7.69 ± 0.74
10 to 20	5.53 ± 1.07	7.19 ± 2.09	8.08 ± 4.33	7.33 ± 0.91	7.15 ± 0.79	6.93 ± 1.29
20 to 40	5.05 ± 1.13	7.85 ± 1.34	8.57 ± 7.65	7.26 ± 088	7.02 ± 1.07	5.69 ± 1.94
Above 40	4.36 ± 0.71	7.70 ± 1.68	8.70 ± 6.67	6.87 ± 1.05	7.18 ± 2.30	4.95 ± 1.48

3.3.7 Conductivity

Electric conductivity in the surface waters of Lake Victoria has increased from 82.82 ± 21.97 in 2005 to 111.85 ± 18.20 μS/cm in 2014; and from 85.00 ± 12.94 μS/cm to 110.59 ± 31.75 μS/cm during the same time period for bottom waters respectively (Table 3.5).

3.3.8 Nutrients

The concentrations of various nutrients have changed appreciably over the past 50 years in Lake Victoria (Table 3.6). Soluble reactive Silica (SRSi) levels decreased from 1.961 mg/L in 1961 to 0.002 mg/L in 2004, while nitrate (NO_3-N) and phosphate (SRP) concentrations have increased during the same period (Table 3.6). Figures 3.9, 3.10, and 3.11 show SRSi, NO_3-N and Total Phosphorus for Lake Victoria portion of Tanzania and illustrate the spatial distribution of these nutrients. The SRSi concentrations were the lowest in the north-eastern part of the lake with values below 0.69 mg/L recorded. Clusters of SRSi with concentrations above 1.80 mg/L were found around Bukoba town and in Mwanza Gulf (Fig. 3.9). Large clusters of high Nitrate-N concentrations (>0.06 mg/l) were found on the western and south-western sides, and a small patch on the north-eastern side around Musoma town (Fig. 3.10).

3.3.9 Chlorophyll-a

The distribution pattern of chlorophyll-*a* concentration in Lake Victoria varies with time and space (Fig. 3.12). The clusters of high *Chl-a* concentrations were found in the north-western and southern sides of the lake. However, these clusters were patchy. A large cluster of low Chl-*a* concentration was found to cover the central and north-eastern parts of the lake (Fig. 3.12). The distribution pattern of Chl-*a* concentration follows closely that of transparency (Fig. 3.8) and nitrates (Fig. 3.10).

3.4 Discussion

Research, and environmental changes, in the Lake Victoria can be recounted from time immemorial – from when measurement instruments were rudimentary to current times when the use of state-of-the-art earth observation technology is ubiquitous. Lehman (2009) gives a good chronology of events and changes in the lake.

Table 3.5 Electrical conductivity at different depth strata in Lake Victoria

Depth strata (m)	Conductivity (μS/cm)					
	2005	2006	2007	2008	2009	2014
Below 10	82.82 ± 21.97	93.35 ± 6.02	103.23 ± 10.33	103.23 ± 10.52	105.10 ± 11.72	111.85 ± 18.20
10 to 20	85.66 ± 13.95	94.46 ± 5.39	100.92 ± 7.94	100.95 ± 4.93	103.77 ± 7.42	108.79 ± 16.74
20 to 40	83.70 ± 14.25	95.36 ± 2.13	98.80 ± 2.92	99.39 ± 2.13	101.81 ± 3.33	107.18 ± 17.63
Above 40	85.00 ± 12.94	95.64 ± 1.07	98.56 ± 1.90	98.57 ± 1.45	100.25 ± 1.52	110.59 ± 31.75

Table 3.6 Some chemical parameters measured from Lake Victoria between 1961 and 2004

Year	SRSi	NO_3-N	SRP	Total P	Reference
1961	1.961	0	0.013	0.047	Talling and Talling (1965)
1988	0.199	0.003	0.007	0.035	Hecky and Bugenyi (1992)
1991	0.056	0.099	–	–	Lehman and Branstrator (1993)
2002	0.001	0.072	0.001	0.096	TAFIRI survey 2002 (unpublished)
2003	0.0003	0.081	0.035	0.084	TAFIRI survey 2003 (unpublished)
2004	0.002	0.075	0.051	0.095	TAFIRI survey 2004 (unpublished)

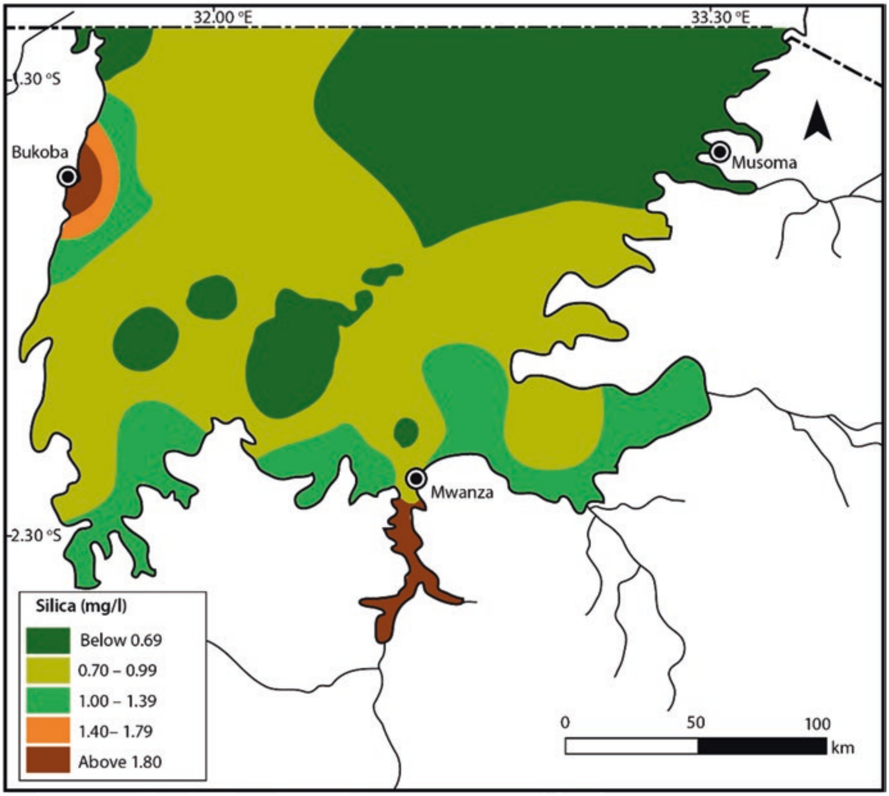

Fig. 3.9 Spatial distribution of Silica concentrations (mg/L) in the Tanzanian part of Lake Victoria between 2000 and 2005

Through these times, there have been significant changes in lake level (Nicholson 1998; Yin and Nicholson 1998; Awange et al. 2008), water quality (Hecky 1993; Lehman and Branstator 1994; Hecky et al. 2010), nutrients dynamics and eutrophication (Stager et al. 2009; Sitoki et al. 2010; van Zwieten et al. 2015), strengthening of thermocline (Stager et al. 2009; Ndebele-Murisa et al. 2010; Sitoki et al. 2010; MacIntyre 2012), organismal composition and abundance (Witte et al. 2009; van

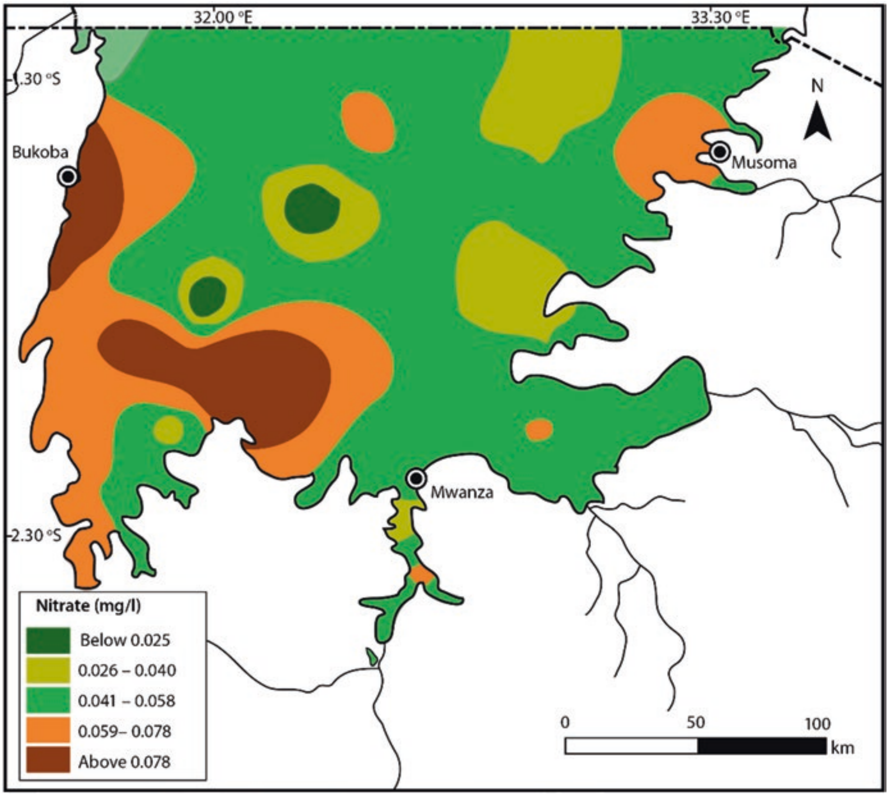

Fig. 3.10 Spatial distribution of Nitrate-N concentrations (mg/L) in the Tanzanian part of Lake Victoria between 2000 and 2005

Zwieten et al. 2015), species extinctions (Witte et al. 1992a; Witte and Goudswaard 1997), and accidental and purposeful introductions of alien invasive species (Seehausen et al. 1997; Hecky et al. 2010; Witte et al. 2011), some of which have devastated and completely changed the ecosystem balance of the lake. Recent changes have even been noticed in the environment outside the lake, but which influences the lake's functioning, such as precipitation and air temperature (Awange et al. 2008; MacIntyre 2012; Marshall et al. 2013).

The minimum air temperatures for Bukoba have been found to warm faster than maximum air temperature in this area. The air temperature has been increasing at a rate of 0.19 °C per year during the past thirty years. This increase in air temperature is consistent with the projected Intergovernmental Panel on Climate Change (IPCC) regional rise in air temperature value (Boko et al. 2007). The period before 2005 had a decreasing trend while for 2005–2015 the temperatures had an increasing trend (see Table 3.1). A comparison of air temperature values between 1985–2004 and 2005–2015 in Lake Victoria (Table 3.1) clearly indicates that the temperatures in the lake region have been warming much faster in recent years (i.e. 2005–2015). The

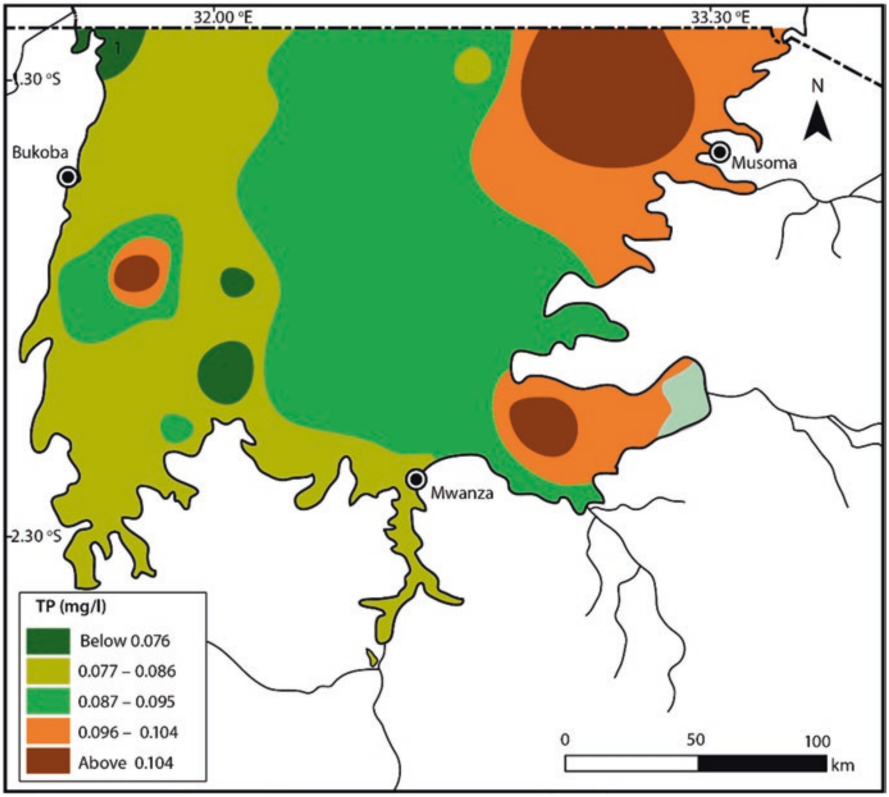

Fig. 3.11 Spatial distribution of total phosphorus concentrations (mg/L) in the Tanzanian part of Lake Victoria between 2000 and 2005

trend of increasing minimum temperature over the last 10 years (2005–2015) was significant (tau = 0.14, p = 0.028) and nearly twice that for the period between 1985 and 2004. The increase in air temperature actually accounts for the fast increase in water temperature during this period, with similar observations recently reported by Marshall et al. (2013).

The rainfall data indicate that the western side of the lake (Bukoba) receives significantly more rains, which is almost equal to that of Mwanza (southern) and Musoma (eastern) combined. This observation conforms to the global rainfall distribution, which tends to be concentrated in time and space (Fujibe and Kobayashi 2007; Adler et al. 2008). Rainfall patterns in the tropics are highly influenced by the Inter-Tropical Convergence Zone (ITCZ) (Stager et al. 2007; Adler et al. 2008; Kizza et al. 2009; Lehman 2009), which drive rainfall in the Lake Victoria region (Okungu et al. 2005; Stager et al. 2007; Kizza et al. 2009). Moreover, the El-Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) events and decadal solar variability also influence the rainfall patterns in the lake (Stager et al. 2007; Lehman 2009; Loiselle et al. 2014). Lake Victoria receives over 80% of its

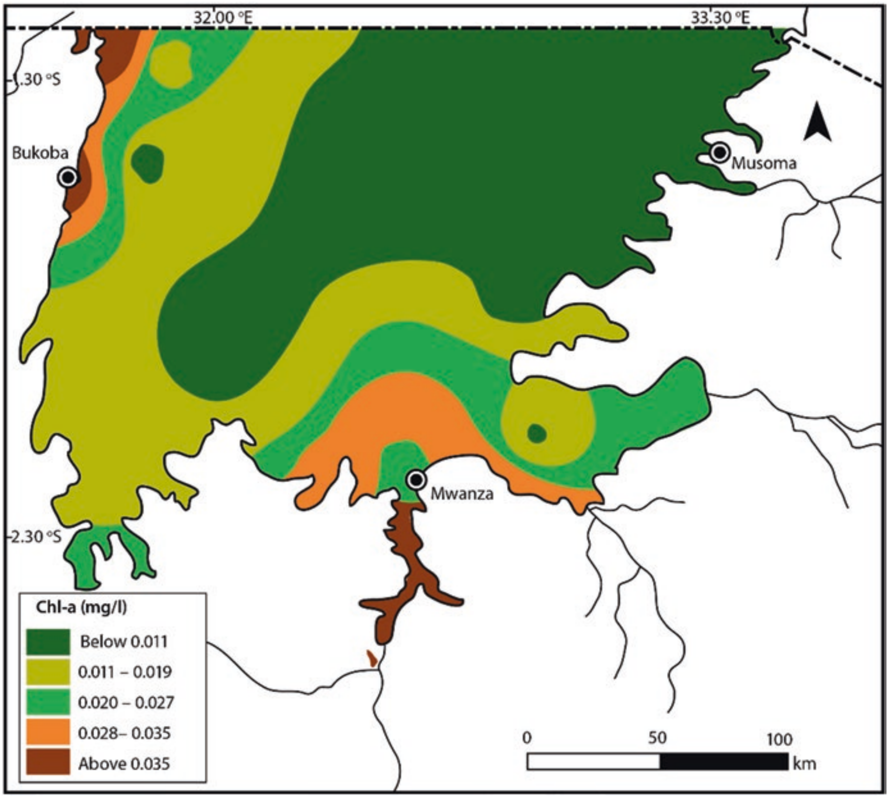

Fig. 3.12 Spatial distribution of mean chlorophyll-a concentration (mg/L) in the surface waters of Lake Victoria, Tanzania (Data from Water Quality and Ecosystem Management Component of LVEMP I)

water from direct rainfall over the lake surface and only 20% from rivers and underground water discharges (Awange et al. 2008). It is because of this fact that the importance of the dynamics in the rainfall and air temperature of Bukoba cannot be ignored. The lake level fluctuations may seriously hinge on the rains from this part of Lake Victoria; that is however, if other regions continue to get drier.

The Lake Victoria water level has been declining over time since the early 1960s. Water level data from the Mwanza south station show a decline from 9.55 m in 1979 to 8.17 m in 2004 – a decline of about 1.4 meters in 25 years. It has been lowering at a rate of 5.5 cm per year between 1966 and 2004. Water levels are also seasonal, following the rainy seasons with a one-month time lag (see Fig. 3.7a). This may indicate that water levels reflect rainfall patterns (Stager et al. 2007). Although the lake water level has declined (van Rijssel et al. 2016), the annual rainfall data do not register an appreciable decline over the time frame that we analysed (Fig. 3.6b). Whilst rainfall records at Bukoba, Mwanza and Musoma remained relatively unchanged between 1985 and 2015, the decline in lake wide water level may have been caused by other factors such as evaporation over the surface of the lake or increased withdrawal of water for consumptive uses within the basin. Similar to Awange et al. (2008), we found that air temperature plays an important role in determining the lake level (see Figs. 3.2, 3.3 and 3.4). Our data show that the minimum air temperature has increased almost exponentially over the past decade, which supports the fact that climate warming could be a major driver of both rainfall and lake level.

Lake Victoria has a large surface area and it is shallow when compared to other East African Great lakes. Therefore, evapotranspiration is an important factor for lowering water level in the lake. This demonstrates that water level change should be given weight in biodiversity vulnerability assessments and ecological research since there is an established linkage between ecological functioning of lakes and their water level (Marshall 1982; Karenge and Kolding 1995; Chifamba 2000; Järvalt and Pihu 2002; Kolding et al. 2003). Also, water level change in lakes can be linked to poor land use practices where deforestation has occurred as a result of urban and industrial development, agriculture intensification and making of charcoal, and animal grazing (Okungu et al. 2005; Stager et al. 2009; Hecky et al. 2010). Lake Victoria is no exception when it comes to deforestation because a vast land surrounding the lake has already been converted to agricultural lands and mining fields, and has huge livestock populations in its vicinity. These human activities are causing increased runoff of sediments and nutrients into the lake which have a significant contribution to poor water quality, increased thermal stability and eutrophication and a shift in phytoplankton species composition and dynamics which are also hampering water visibility (Hecky 1993; Stager et al. 2009; Hecky et al. 2010).

Over the course of the Lake Victoria Environmental Management Project (LVEMP), as illustrated in this chapter, waters with poor visibility were observed around towns and in the vicinity of large rivers draining farmlands and areas with extensive deforestation and poor land use (see Fig. 3.8), such as the Simiyu River, which is the largest nutrients and sediment contributor into Lake Victoria (Dubi 2006). Water visibility was generally poor due to algal blooms and the nuisance water hyacinth, such that transparencies less than 2 m were commonplace in Lake Victoria. Similar values were also occasionally measured during the nineteenth and twentieth centuries (Worthington 1930; Akiyama et al. 1977; Ochumba and Kibaara 1989; Hecky 1993; Scheren et al. 2000). However, recent surveys indicate some improvements in water transparency where values greater than 2 m have been measured in waters of different depths since 2007 (see Table 3.2). Changes in transparency are an indication of changes in sediment load and microalgae suspension. Poor visibility can have far reaching consequences, especially in regards to hybridization and loss of endemic cichlid fish which rely heavily on visual cue for mating (Seehausen et al. 1997; Witte et al. 2013; van Rijssel et al. 2016); and can negatively affect fish production, distribution, biodiversity and primary productivity (Silsbe et al. 2006; Witte et al. 2011; Cornelissen et al. 2015).

Similar to other great lakes of Africa (O'Reilly et al. 2015), water temperature in Lake Victoria vary with seasons. Both surface and deepwater temperatures have increased over time from as low as 22 °C during the cool dry seasons to as high as 26 °C during the hot rainy season between 1973 and 1974 (Akiyama et al. 1977; van

Rijssel et al. 2016). A comparison of the 2006–2009 water temperature with previous data in Lake Victoria (Table 3.3) clearly indicates an increase in water temperature. The surface water temperatures for 2006–2009 ranged between 24 and 26 °C, which are higher by one degree Celsius from the measurement taken during the 2002–2004 period (see Table 3.3). Vertical mixing in Lake Victoria, especially during the cool dry season were common events. In recent years however, the lake's thermal structure has changed dramatically with unprecedentedly less mixing, a stable thermocline and an expanding and prolonged hypolimnetic hypoxia (Hecky et al. 1994, 2010; Wanink et al. 2001; Lehman 2009; MacIntyre 2012). As a consequence, the oxycline depth became significantly shallow (Hecky et al. 2010).

According to Wanink et al. (2001), hypoxia—the deficiency of dissolved oxygen in water—which was rare and occurred only in deep waters in the 1980s, is now more frequent and is spreading into shallow waters (Mugidde et al. 2005). Similarly, anoxia has been reported in water depths below 45 m and offshore waters (Hecky et al. 1994). In contrast to deeper and offshore waters however, surface waters are always saturated with oxygen (Mkumbo 2002; Ngupula et al. 2012). The shallow inshore waters (<30 m) were found with DO concentrations ranging between 6.6–7.8 and 10.3 mg/L in the surface waters, while the offshore water stations had DO concentration of about 0.28 mg/L in the bottom waters. However, mean oxygen concentrations between 2002 and 2004 varied from 8.02 ± 0.73 mg/L in the surface waters to 3.2 ± 4.36 mg/L in the bottom waters at 68 meters deep, while DO in the littoral waters ranged from 8.4 ± 1.2 to 10.0 ± 0.9 mg/L (TAFIRI Survey Report 2005). Furthermore, DO values for the period 2007–2014 are consistently higher even in deep waters (see Table 3.4).

Changes in nutrients dynamics in Lake Victoria have been dramatic and challenging to deal with from the management perspective. Our data show that soluble reactive silica has declined in recent decades and caused a change in the siliceous phytoplankton abundance and composition (Hecky 1993; Verschuren et al. 1998; Lehman 2009; Ngupula et al. 2014). Because silica mineralizes in anoxic conditions, it follows that its decline is related to the unprecedented development of hypoxia in Lake Victoria (Verschuren et al. 1998; Hecky et al. 2010). As a consequence of low silica concentration in the lake, larger and nutritious diatom species such as *Melosira* sp., *Stephanodiscus astraea* and *Aulacoseira nyassensis* var. *victoriae* have become rare while smaller diatoms such as *Nitzschia acicularis* are dominating the pelagic diatom community (Lehman and Branstator 1994; Verschuren et al. 2002; Ngupula et al. 2011; Cornelissen et al. 2014; Mbonde et al. 2015). This change may have had a bearing on the disappearance of the indigenous fish species, *Oreochromis esculentus* and *O. variabilis*, which feed predominantly on large diatoms such as *Melosira*/*Aulacoseira nyassensis*.

While some areas of Lake Victoria are already nutrients-saturated (Silsbe et al. 2006), spatio-temporal nutrients enrichment capable of increasing primary production beyond the current levels are possible in the lake, such as has been demonstrated by Cornelissen et al. (2014). Both nitrogen and phosphorus loading have been dramatic, affecting phytoplankton composition from a formally balanced plankton community to one dominated by cyanophytes, which constitute approximately 70%

of all phytoplankton biomass (MacIntyre 2012). We found that nitrates are more abundant in the western side of the lake, probably in relation to high rainfall. Otherwise nitrogen in the lake is dominated by N-fixation, which is estimated to supply an average of 814 mmol m^{-2} $year^{-1}$ (Lehman 2009). However, internal P loading has increased as a result of increased hypoxia (Hecky et al. 2010) and atmospheric deposition's contribution to P loading is more than half of all allochthonous phosphorus, which is high (Scheren et al. 2000; Tamatamah et al. 2005). The spatial distribution of phosphorus indicate that the eastern side of the lake has higher phosphorus concentration probably brought in through the Mara River and Simiyu River both of which drain agricultural lands and areas with large livestock populations.

Chlorophyll-*a* concentration, which is a proxy of phytoplankton biomass, has also increased, especially in the inshore areas, probably due to lack of significant and prolonged mixing events (Hecky et al. 2010; Ngupula et al. 2011; MacIntyre 2012; Loiselle et al. 2014), and excessive nutrients loading which resulted into algal blooms (Mugidde 1993; Msomphora 2005; Ndebele-Murisa 2014). Our data show a dominance of high chlorophyll-*a* concentration in the western and southern sides of the lake during the period 2002–2004 (see Fig. 3.11). However, these results are different from those of Ngupula et al. (2012), Mbonde et al. (2015), which indicate predominantly high chlorophyll-*a* concentrations in the eastern side of the lake. This feature has also been related to presence of sheltered bays that prohibits connectivity between bays and offshore waters, land-based nutrients, and many rivers and streams (Semba et al. unpublished manuscript; Mbonde et al. 2015) and are dominated by toxic *Microsystis* spp. (Mbonde et al. 2015; Sekadende et al. 2005).

3.5 Conclusion and Recommendations

The Lake Victoria environment has changed as a consequence of both anthropogenically driven poor land use, livestock grazing, urban pollution, population growth and climatic factors. Nutrients loading from atmospheric deposition and land runoff account for 90% and 94% of phosphorus and nitrogen, respectively, in Lake Victoria (Scheren et al. 2000); which may have benefited the commercial fishery of the lake (Kolding et al. 2008). However, its impacts have been far reaching and have negatively caused the deterioration of the lake's water quality, thereby affecting ecosystem services, including the aesthetic value of the lake water and beaches.

The declining water level in Lake Victoria pose significant but poorly appreciated threats to aquatic ecosystems and the riparian communities who directly benefit from the goods and services provided by the lake for their livelihood. For instance, shallow bays are mostly used as breeding and feeding grounds for a number of species in the lake, and because these habitats are likely to disappear as the lake water level continue to decline, both the biodiversity of the lake and community livelihoods are in jeopardy.

In light of the discussion and conclusions above, and in order to rescue the lake from entering a hypereutrophic state, upon which remedial efforts may not be useful, we recommend the following:

- Deliberate management efforts to improve land-use management within the catchment of Lake Victoria should be mobilized. Improving land-use management practices has triple benefits: (i) controlling further nutrients loading into the lake, (ii) reducing sediment loading which may significantly reduce the lake level and cause species extinctions, and (iii) avoiding or reducing unwanted species hybridization.
- Also, there is a need to control direct industrial and domestic wastes discharge into the lake. These wastes normally flush more nutrients, especially phosphorus into the lake, which is required for water hyacinth growth and proliferation. Reducing inputs of P into the lake will starve the weed thereby improving the lake's aesthetic value and increasing the availability of nearshore habitats for breeders and juvenile fish to nursery. It is expected that the reduced plant biomass will also improve the lake's transparency, expand the euphotic zone and reduce organic loading to the stratified, anoxic deep waters and ultimately improve the productivity of the demersal fish and fisheries.
- We also recommend the use of earth observation technology and lake monitoring buoys to collect water quality data. Remote sensing data for example can be used to provide advanced early warning when signs of deteriorating water quality are observed. Similarly, *in-situ* high frequency data from buoy can be used to document phenomena that are very hard to measure from snapshot monthly sampling.
- Finally, we recommend the use of citizen science for monitoring basic water quality parameters, such as plankton blooms, hypoxia (if fish kills are observed), water hyacinth coverage, and use of simple instruments to measure water temperature.

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Chapter 4
Fish Biology and Life History Indicators

E.F.B. Katunzi, Yunus D. Mgaya, O.C. Mkumbo, and S.M. Limbu

Abstract Life history traits like growth, reproduction, food and mortality are principal factors in the survival of the fish. This chapter examines the life history indicators of three commercial fish species in Lake Victoria, namely Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*) and the cyprinid known as 'Dagaa' (*Rastrineobola argentea*). The size at first maturity for Nile perch has been declining due to stress in the population caused by heavy exploitation, changes in food availability and deteriorating water quality parameters, particularly dissolved oxygen concentration. The fish exhibits ontogenic shifts in food. *R. argentea* has an offshore surface dwelling behaviour with about 68% found distributed in waters of more than 40 m depth. Its size at first maturity varies from place to place. *R. argentea* breeds throughout the year but with distinct peaks during the rainy season. An increase in fecundity has been observed in Nile tilapia and it is considered a mechanism to compensate for the intensive fishing pressure in the lake. Studies indicate an increase in size and growth parameters for Nile tilapia despite the heavy fishing pressure as a result of increased demand in local and foreign markets. The success of the species could be due to the ability of the species to expand their niche. It has diversified its food to include *Caridina nilotica*, chironomids, chaoborids, molluscs and bottom detrital matter. An ecosystem approach guided by a precautionary principle is required in order to manage the fishery resources in Lake Victoria and to ensure their sustainability.

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4.1 Introduction

Life history parameters, when monitored over time, can give an indication of the performance of a species in an ecosystem. They give a direction of success or failure, in which case, appropriate measures can be devised accordingly. Life history traits like growth, reproduction, and mortality are regarded as principal factors in the survival of fish (Stearns 1992; Matsuishi et al. 2006; Murua 2014). The fish will be forced to increase the growth rate and switch to early reproduction when under pressure due to exploitation and other environmental changes (Heino and Godø 2002). Due to a compromise between reproduction and somatic growth, this early maturation can cause stunted growth (Stearns 1992; Tsikliras et al. 2007). However, for the larger fishes, the reaction could be an increase in fecundity. This chapter examines life history indicators of three commercial species in Lake Victoria, namely, the Nile perch, the Nile tilapia and the cyprinid dagaa (*R. argentea*).

4.2 The Nile Perch

The Nile perch (*L. niloticus* Linnaeus) is a predatory fish of high commercial and recreational value. It can grow to a length of two meters and a weight of 200 kg (Geheb et al. 2008). It was introduced into lakes Kyoga, Nabugabo and Victoria in Uganda from Lake Albert during the 1950s and early 1960s (Hamblyn 1961; Geheb et al. 2008). Eight specimens from Lake Turkana were introduced in the Kenyan part of Lake Victoria at Kisumu in 1963 (Odero 1979). The fish was introduced to feed on the small-sized haplochromine cichlids, which were at that time abundant and relatively unexploited for conversion into larger fish of greater commercial and recreational value (Anderson 1961; Downing et al. 2014).

4.2.1 Reproduction

Size at First Maturity

The length at first maturity (Lm_{50}) is often used as an indicator in relation to changes in the mean length of the population being fished. Lm_{50} is the point on the curve where 50% of the fish are mature (Fontoura et al. 2009). A research carried out by LVFRP (Cowx 2005) revealed that about 20% of the fish captured in trawl surveys were mature, and of these, females represented about 30%.

Soon after the Nile perch introduction, the size at first maturity of male Nile perch was between 30–34 cm total length for males, and 33–35 cm for females (Okedi 1974). The length at first maturity of 54 cm for males and 69 cm for females was recorded by Acere (1985). The trend of events changed to males maturing at

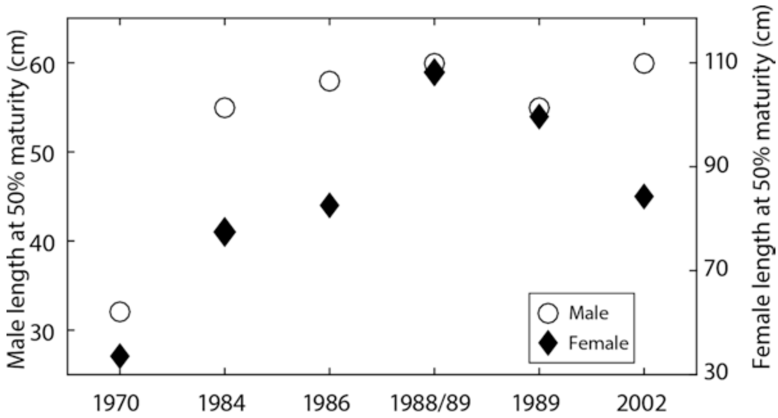

Fig. 4.1 Trends in size at 50% maturity for *L. niloticus* (Sources: 1970: Okedi (1971); 1984: Acere (1985); 1986: Ogutu-Ohwayo (1988); 1988/89: Ligtvoet and Mkumbo (1990); 2002: Mkumbo (2002)). Note: The low Lm50 values in 1970 and 1984 could be attributed to the various authors using a different (maturity) assessment method

50–65 cm and females at 60–95 cm as per Ogutu-Ohwayo (1988). In Tanzania, the size at first maturity for females and males in the Mwanza Gulf, Tanzania (1988–1989) was at 110 cm and 60 cm TL, respectively (Ligtvoet and Mkumbo 1990). In 2002, Mkumbo (2002) recorded a decrease in size when she noted the lengths at maturity for males and females to be 54 cm and 77 cm respectively (Fig. 4.1). The declining trend in the size of maturity points to stress in the population, which could be a result of heavy exploitation, changes in food availability and deteriorating water qualityparameters in the lake environment (Njiru et al. 2007; Hecky et al. 2010).

Generally, males of *L. niloticus* attain maturity at a smaller size than females based on the available growth rate data (Hughes 1992; Mkumbo 2002). Using the parameters of the von Bertalanffy growth function and the relationship of $t_m = t_0 - \ln(1 - L_m/L_\infty)/K$ (Froese et al. 2000), where t_m is the age at first maturity and L_m is the size at first maturity, Mkumbo (2002) calculated the age at first maturity for males and females of *L. niloticus* at 1.6 years and 2.5 years respectively.

Breeding Cycle

Mature fish (ripe and running condition) were found throughout the year (Ligtvoet and Mkumbo 1990; Mkumbo 2002) with a peak in the proportion of individuals in advanced stages of maturation occurring in November and December and a smaller peak in May/June. The former and latter peaks coincide with the start and end of the rainy season, respectively (Acere 1985). It should be pointed out that since the patterns of dry and wet seasons do not run concurrently in all parts of the lake, the breeding cycle of the Nile perch is not expected to be identical over the whole lake. Ligtvoet and Mkumbo (1990) reported that the Nile perch preferred to spawn in shallow sheltered areas, and nursery grounds are located at a wide range of 2–57 m depth.

4.2.2 Length Frequencies

The length frequency trends over the years and proportion of fish larger than 80 cm total length (TL) are depicted in Figs. 4.2 and 4.3. The length frequency data presented in Fig. 4.2 were collected using different trawls (in different zones) and hence should be interpreted with caution. The data collected in 1985–1990 on the Tanzanian side with bottom trawls has confirmed a sharp fall in percentage compositions of fishes larger than 80 cm total length (Fig. 4.3). For the years after 1999, there is a progressive increase in the quantity of larger fishes. Increased fishing effort could be the main cause of the observed changes. However, environmental factors such as the lake's limnochemistry could also explain the observed fluctuations in fish populations.

4.2.3 Growth

From Lake Victoria, specimens could grow up to 190 cm TL (Acere, 1985) and 200 cm TL (Okemwa 1984). Females grow to a much larger size than males. Ligtvoet and Mkumbo (1990) reported the growth increments of 28, 28 and 21 cm yr.$^{-1}$ for three fishes that were tagged in the Mwanza area at lengths of 32, 47 and 51 cm respectively. Asila and Okemwa (1999) reported a growth increment within that range (29 cm yearr^{-1}) from tagged fishes. The differences and inconsistencies observed in the estimated growth parameters could possibly be explained by the differences in the size of the catch populations. With bigger sizes in the sample, the higher the L, the lower the K (Fig. 4.4).

4.2.4 Distribution

L. niloticus is endemic in lakes Albert, Rudolf, Turkana, Tana, Chad, and the Nile River basin; but introduced in lakes Victoria and Kyoga. The Nile perch has a lake-wide distribution, which depends on dissolved oxygen concentration and depth ranging from 0 to 60 m. However, juveniles of the length <30 cm in lakes Chad, Turkana and Albert are mainly distributed in the shallow inshore waters (Hamblyn 1962; Gee 1966). The littoral rocky habitat is possibly one of the few habitats in Lake Victoria that has not been invaded by *L. niloticus* (Witte et al. 1991). This habitat has a spectacular assemblage of haplochromines not known to exist elsewhere in the lake. The highest catch rates of the Nile perch in the Tanzanian area in 1985 were obtained from waters between 16 and 50 m deep (Goudswaard and Witte 1985).

The batho-spatial distribution pattern exhibited a decline in *L. niloticus* stock abundance with depth, similar to that observed in 1969/1970 (Kudhongania and Cordone 1974), but with differences in the depth ranges of high abundances (Mkumbo 2002). Results of bottom trawl surveys conducted under LVFRP (1999–

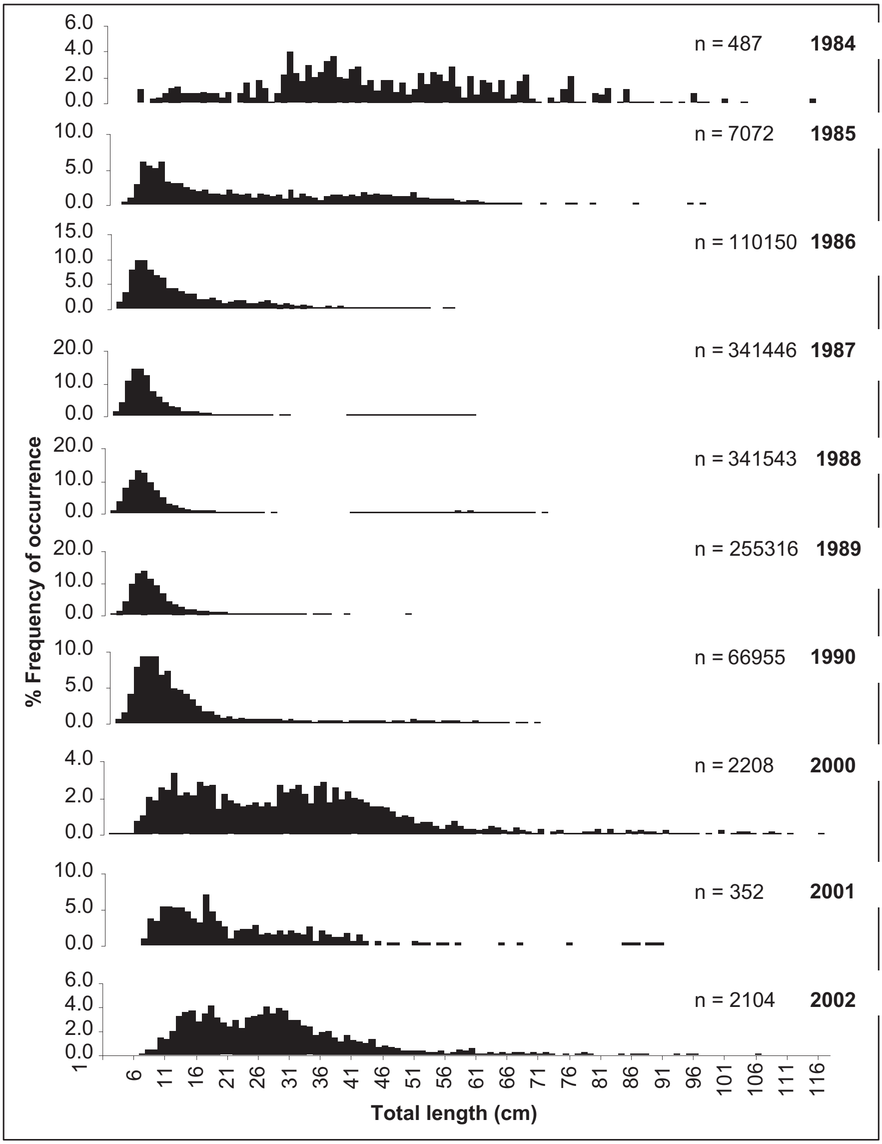

Fig. 4.2 Length frequency distribution for *L. niloticus* in the experimental catches from the Tanzanian part of Lake Victoria (Data from TAFIRI Unpublished Reports)

2001) recorded the highest catch rates at depths of 4 m to 20 m with a remarkable decline in catch rates at depths below 50 m. Unlike the 1960–1970 surveys, which recorded a drop in catch rates below 70 m, the mean catch rates dropped abruptly below 50 m during the LVFRP survey (Mkumbo 2002). This is probably linked to changes in the physico-chemical characteristics of the lake and the presence of a

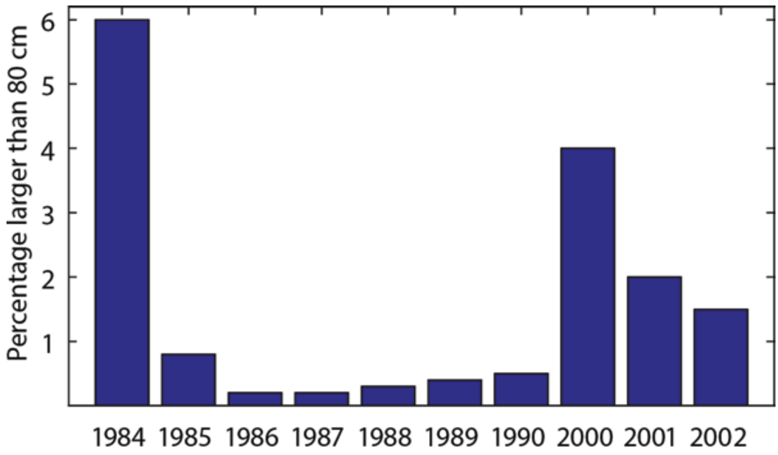

Fig. 4.3 Proportion of fish larger than 80 cm TL for *L. niloticus* (Data from TAFIRI, Unpublished Reports)

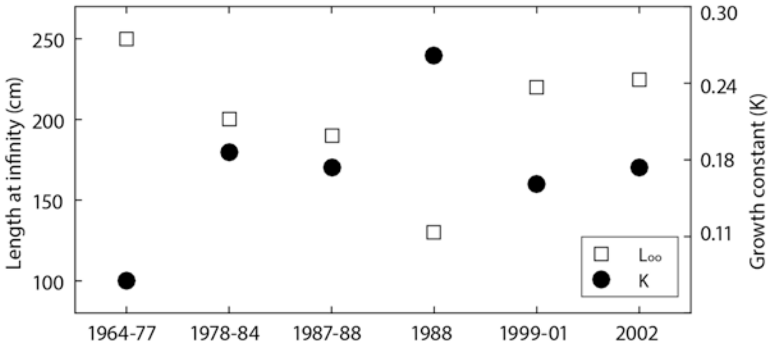

Fig. 4.4 von Bertalanffy growth parameters, length at infinity (L∞) and growth constant (K) for *L. niloticus* (Sources: 1964–1977: Acere (1985); 1978–1984: (Asila and Ogari 1988); 1987–1988: Ligtvoet and Mkumbo (1990); 1998: Asila and Okemwa (1999); 1999–2001: Mkumbo (2002); 2002: (Muhoozi 2002))

low dissolved oxygen (hypoxic) layer below 50 m (Hecky et al. 1994; Wanink et al. 2001; Sitoki et al. 2010). The hypoxic layer in deeper waters is not a permanent feature since oxygen concentrations as high as 6.67 mg/L at 67-m depth in August, 5.7 mg/L at a depth of 55 m in September 2000 and 5.8 mg/L at 50 m deep in February 2001 have been reported (Mkumbo 2002).

4.2.5 Food and Feeding

Feeding Habits and Adaptations

Between 1968 and 1977, haplochromines were the dominant prey of most sizes of the Nile perch in Lake Victoria. By 1988, the major types of prey eaten by the perch in Lake Victoria had changed to *Caridina nilotica*, anisopteran nymphs, Nile perch juveniles, *R. argentea* and tilapiines with very few haplochromines (Ogari and Dadzie 1988; Mkumbo and Ligtvoet 1992). These remained the major types of prey of the Nile perch in Lake Victoria between 1995 and 2000 with proportions of haplochromines increasing significantly (Fig. 4.5).

A decline in the importance of haplochromines in Lake Victoria was accompanied by a relative increase in *R. argentea* (Mkumbo and Ligtvoet 1992). However, as haplochromine stocks improved, the Nile perch reverted to feeding more on haplochromines (Mkumbo 2002) suggesting that the fish shifts to *R. argentea* in the absence of haplochromines. It also suggests that *R. argentea* may be a less preferred prey than haplochromines (Kishe-Machumu et al. 2012; van de Wolfshaar et al. 2014).

Ontogenic Shifts in Diet

Nile perch exhibits a clear ontogenic shift in diet at various sizes (Downing et al. 2013; Nyboer and Chapman 2013; Nkalubo et al. 2014). For example, while Nile perch individuals with less than 20 cm total length (TL) fed on *C. nilotica, R. argentea*, anisopteran nymphs and chironomids; individuals with TL from 20 cm to 60 cm mainly ingested *R. argentea*, anisopteran nymphs, *C. nilotica*, tilapiines, juvenile Nile perch and to a lesser extent haplochromines. Nile perch with 60–100 cm TL mainly ate *R. argentea,* Nile perch juveniles, tilapiines and haplochromines, while individuals with >100 cm TL depended almost solely on tilapiines and Nile perch juveniles (Nkalubo et al. 2014). The ontogenic shift in the diet of the Nile perch is further illustrated by studies done in Tanzania and Kenya (Ogari and Dadzie 1988; Kishe-Machumu et al. 2012). The diets of the Nile perch with total lengths <20 cm were dominated by *C. nilotica*, which contributed more than 70% of the prey items (Mkumbo 2002).

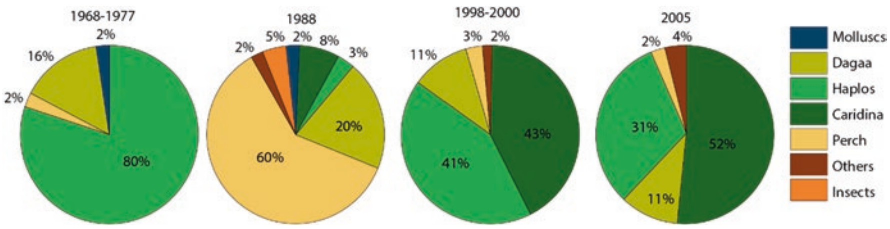

Fig. 4.5 Shifts in feeding habits of the Nile perch in Lake Victoria for the period of 1968–2005 (Data from Unpublished IFMP Report 2005)

Between 20 cm and 60 cm TL, *C. nilotica* dominance decreased from 48% to about 30%, as the Nile perch switched to feeding on haplochromines, which contributed more than 70% of their diet. In large fish (>90 cm TL), the Nile perch became cannibalistic, feeding on its own juveniles, which contributed about 30% of the diet. Other fish prey such as *Clarias gariepinus* (7%), *Oreochromis* species (8%) and *Barbus profundus* (7%), also became important, and the contribution of haplochromines declined to about 50%. The contribution of dagaa was low (<16%) in all sizes of Nile perch <100 cm TL, and absent in the stomachs of larger fish (Mkumbo 2002).

4.3 The Silver Cyprinid (*Rastrineobola argentea*)

4.3.1 Introduction

R. argentea (locally known as dagaa) is endemic to the Victoria Nile and lakes Kyoga, Nabugabo and Victoria (Corbet 1961; Greenwood 1966). The species has been able to survive alongside the voracious Nile perch *L. niloticus* (Ogutu-Ohwayo 1995; Taabu-Munyaho et al. 2016). Over a long period of time the fish has not attracted the attention of both scientists and investors. This could probably have been due to its small size and low abundance especially before the decline of the haplochromines. The exploitation of dagaa is first reported as a light fishery in the mid-1960s (Okedi 1981). The fishing is reported to have flourished after the reduction of the haplochromines due to overfishing and predation (Barel et al. 1991; Reynolds et al. 1995). Currently the species is second to the Nile perch in abundance and importance in the lake's fisheries.

4.3.2 Distribution

R. argentea has been described as an offshore surface dweller (Greenwood 1974). The majority of the biomass of *R. argentea* (an average of 68%) is distributed in waters of more than 40 m depth (Tumwebaze et al. 2007). However, *R. argentea* was later found in the pelagic waters probably because of displacement by the more competitive zooplanktivorous haplochromines while following the downward movement of the zooplankton (Getabu et al. 2003). Further colonization of the species followed the disappearance of the demersal haplochromines. Parasitism also was known to have an impact on the distribution of the fish. For example, juveniles and parasitized adults stay near the surface throughout the day (Wanink 1992). Physical environmental factors like light and oxygen also have an impact on the distribution of fishes. *R. argentea* also migrates diurnally within the water column. It occupies the surface waters at night and deep waters during the day.

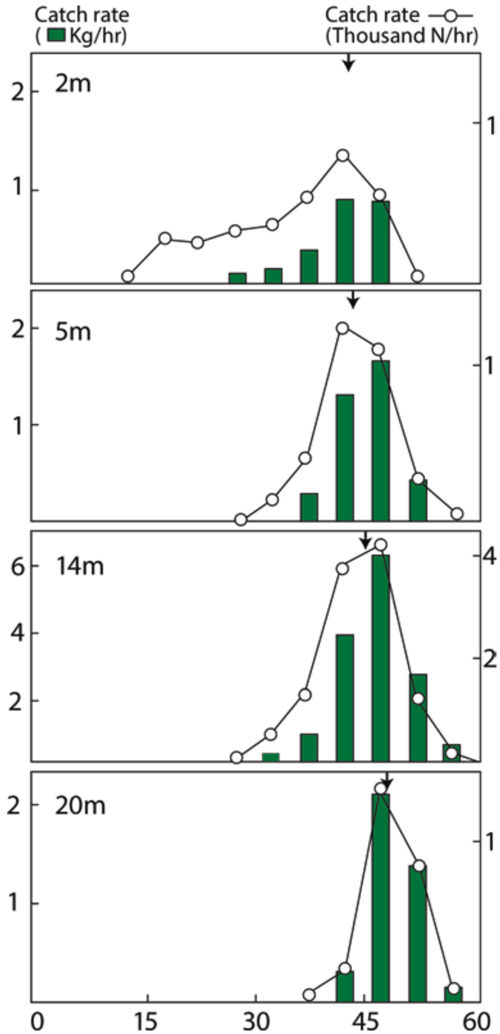

Fig. 4.6 Horizontal distribution of *R. argentea* over five stations in the Mwanza Gulf (Redrawn from Wanink 1998)

Wanink (1992) observed majority of the adult fishes to be concentrated in the upper part of the water column in the night but during daytime they were found close to the bottom with a smallpopulation at the surface but mostly parasitized by *Ligula intestinalis* (Oyoo-Okoth et al. 2010). Juvenile dagaa >35 mm SL were abundant in daytime surface trawls but could not be caught at night, which may indicate that they occupy intermediate depths. Night catches from the surface trawl show that the size of adult dagaa increases with water depths and distance from the shore (Wanink 1998) (Fig. 4.6).

4.3.3 Reproduction

Size at First Maturity

Size at first maturity of *R. argentea* has been reported to vary from place to place. Wanink (1998) reported that females from the Mwanza Gulf mature at 36 mm standard length. Outside the gulf, *R. argentea* has been found to mature at 39 mm SL for females and 44 mm SL for males (Bayona et al. 2003).

Absolute Fecundity

The absolute fecundity (± SD) of dagaa in 1987 was 1073 ± 313 eggs (n = 22). However, Okedi (1974) reported fecundity of 2282 ± 1065 (n = 36) for the period between 1970 and 1974. The difference was significant (Mann-Whitney U-test; $p < 0.01$). This could be a result of dwarfism since a positive correlation exists between the size of dagaa and absolute fecundity.

Breeding

R. argentea breeds throughout the year but with distinct peaks. The peak was reported in March in the Mwanza Gulf (Wanink 1998). Protracted breeding indicates that the species has a high capacity to replace itself.

4.3.4 Length Frequency Distributions

The modal lengths have been changing since 1970–2005 from 7 cm to 4.2 cm (Fig. 4.7). The decrease has been a result of increased fishing pressure, and reduction in somatic growth at the expense of reproductive expansion (Wanink 1998). A further decrease in the mean modal length of the population for the years 2002 and 2005 has also been observed (Nsinda Unpublished data).

4.4 The Nile Tilapia

4.4.1 Introduction

The Nile tilapia, *Oreochromis niloticus*, was introduced into Lake Victoria in the 1950s together with other non-indigenous tilapiines, including *Oreochromis leucostictus* Trewavas, *Tilapia zillii* Gervais and *Tilapia rendalii* Boulenger from Lake

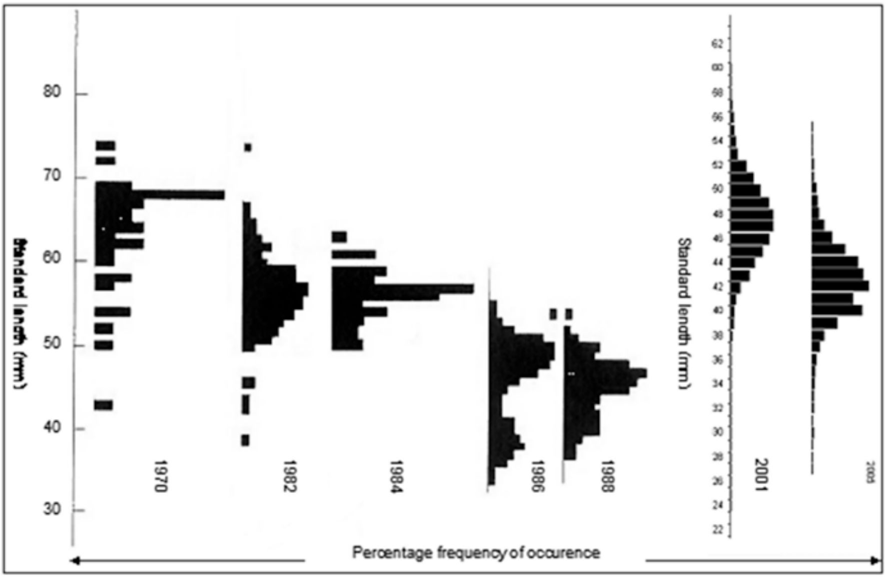

Fig. 4.7 Length frequency distributions of *R. argentea* (Source: Wanink (1991); for 1970–1988 data; Nsinda, unpublished data 2005). Dagaa were caught by gillnets in earlier years (1970–1988) and by fishers' nets in the years between 2001 and 2005

Albert (Welcomme 1968). The fish, however, had been introduced into the lake as early as 1930s (Lowe-McConnell 1958; Fryer and Iles 1972), but only established in the late 1960s (Welcomme 1968) along with the voracious predator Nile perch, *L. niloticus* Linnaeus. *O. niloticus* appeared in commercial catches in 1960 constituting less than 1% of the landings (Welcomme 1968). By 1965, it featured prominently in the commercial catches and currently it is the most commercially important tilapiine, whereas the native species of *O. variabilis* and *O. esculentus* have largely disappeared (Witte and van Densen 1995; Othina and Tweddle 1999). Currently, *O. niloticus* constitutes the third most commercially important fishery in Lake Victoria (Nunan 2014), after the introduced *L. niloticus* and the endemic cyprinid *R. argentea* Pellegrin.

4.4.2 Food

O. niloticus was predominantly a phytoplanktivorous and bottom feeder during the earlier stages of its colonisation of the lake (Welcomme 1968). However, later observations indicated that in Lake Victoria, the food of *O. niloticus* became more diversified and including *C. nilotica*, chironomids, chaoborids, molluscs and bottom detrital matter (Kaggwa et al. 2009) (Fig. 4.8).

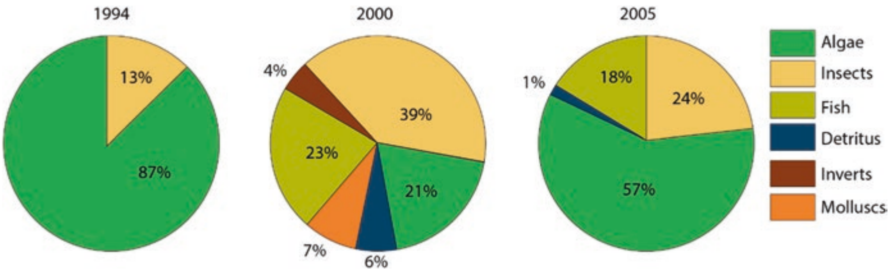

Fig. 4.8 Shifts in feeding habits of the Nile tilapia for the period of 1994–2005 (Data from Unpublished IFMP Report)

Njiru et al. (2004) found that the diet of *O. niloticus* varied with increasing size, although all size classes >5 cm TL consumed all important food items. Zooplankton (cladocerans and copepods) were the major food of *O. niloticus* under 5 cm TL, and were of little importance to fish larger than 15 cm TL. Insects were also of little importance to the diet of small *O. niloticus* (<5 cm), but were major food items of larger fish. Algae, fish and plant material were consistently important to all size groups below 55 cm TL. Fish <10 cm TL did not consume molluscs.

4.4.3 Fecundity

The fecundity of *O. niloticus* has increased from 340–3,706 eggs for fish of 17–57 cm TL (Lowe-McConnell 1958) to 864–6,316 eggs for fish of 28–56 cm TL (Lung'ayia 1994) to 1,240–6,600 eggs for fish of 27–56 cm TL (Chande and Mhitu 2005). The increase in fecundity could also be a mechanism to compensate for the intensive fishing pressure in the lake. In stable environments, fish put more effort into somatic growth as opposed to gonadal development. This tactic is more likely to increase their chance of survival and reproduction in subsequent years (Cowx 1998).

4.4.4 Length Frequency Distributions and Size at First Maturity

The percentage frequency distributions over the years are shown in Fig. 4.9. Time series data on the population characteristics of the species is very scanty on the Tanzanian side. However, trawl data for the years 1984–2002 indicates an increase in the proportions of relatively bigger fishes despite the heavy fishing pressure because of increased demand in local and foreign markets. The success of the species to sustain the fishing pressure could be due to the ability of the species to expand the food range (Njiru et al. 2004). This is further supported by the increase

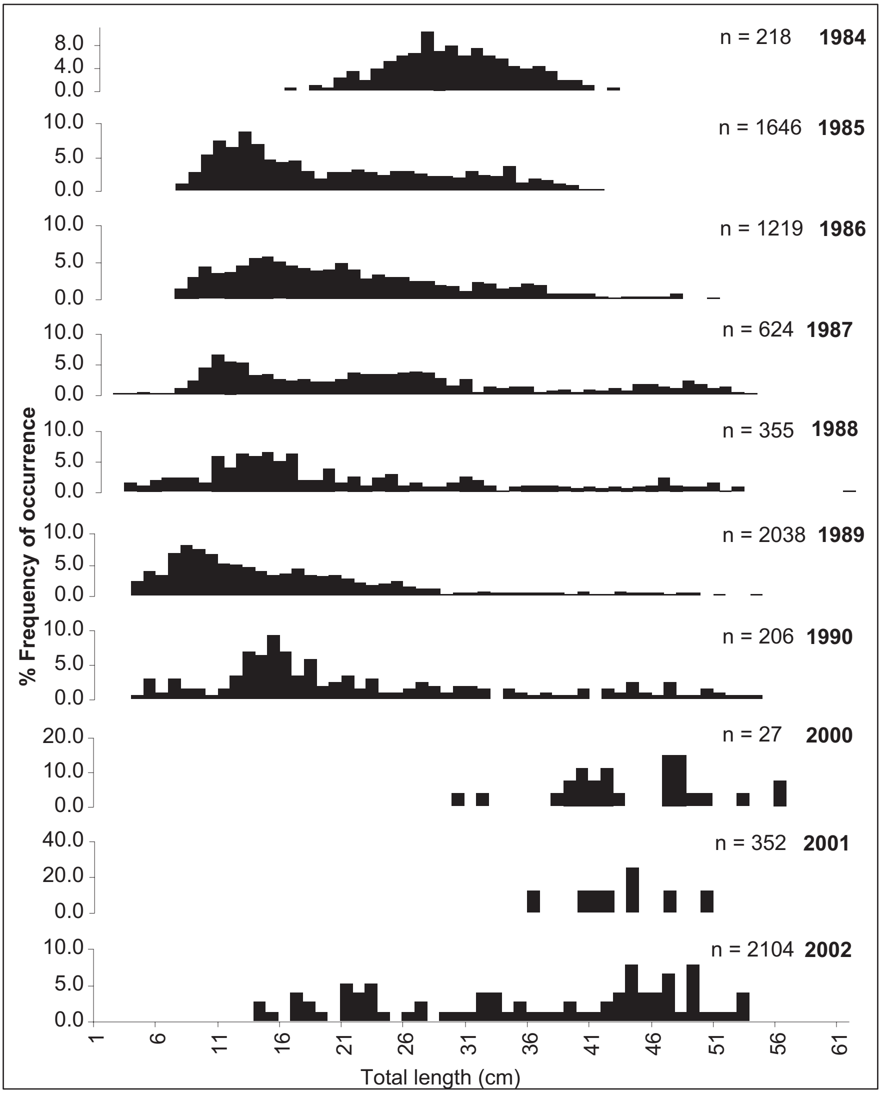

Fig. 4.9 Shifts in feeding habits of Nile tilapia for the period of 1994–2005 (Data from Unpublished IFMP Report)

in the growth curvature K for various years as follows: 0.25 for 1985–1986 (Getabu et al. 2002), 0.35 for 1980–1990 (Dache 1994), 0.56 for 1988–2000, all in Kenyan waters (Njiru 2003). It can also be said that the increase in fishing effort on the Tanzanian part of the lake might possibly explain the decrease in the size at first maturity of the *O. niloticus* in Lake Victoria (Fig. 4.10).

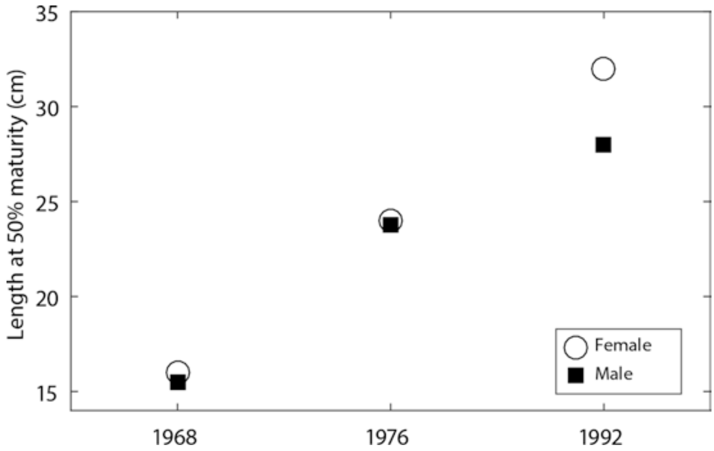

Fig. 4.10 Length at 50% maturity for *O. niloticus* (For 1968 fish length measured as SL (cm), the rest as total length) (Sources: 1968: Welcomme (1968); 1976: Wanjala and Marten (1976); 1992: Ogari and Asila (1992))

4.5 Conclusions

The data on important life history indicators (e.g., length at maturity; growth and mortality estimates; length-frequency data; trophic interactions; spatial and temporal distribution, and fecundity) for the three commercially important species is sparse and does not form a long-term series to facilitate definitive conclusions about the resources. However, the intervention by LVEMP and (to a large degree) LVFRP has provided some data and information, which form the basis for the following concluding points on the Nile perch:

- The batho-spatial distribution pattern exhibited a decline in Nile perch stock abundance with depth, an indication of a reduction in aerated habitats as a result of eutrophic conditions.
- The Nile perch disrupted the ecosystem by simplifying the food web through the elimination of haplochromines from many interactions, leading to shortening of food chain.
- Feeding habits of the Nile perch have changed concomitantly with faunal changes in the lake.
- The size at first maturity of the Nile perch exhibited a falling trend. This drop could be attributed to an increase in fishing pressure, changes in food availability and the lake environment.

4.6 Recommendations

- There is a need to make further investment in studies leading to a better understanding of the lake environment so that the factors driving diversity, abundance and community structure are identified. This is important because there is a strong link between fish productivity and the health of the ecosystem.
- The heavy exploitation of the Nile perch can be alleviated through the imposition of closed seasons and/or closed areas. These management options are difficult to implement because of scarce knowledge on the spawning behaviour, breeding and nursery areas. As such, there is a need to conduct thorough investigations on the ecology of the Nile perch in the Tanzanian part of Lake Victoria as precursor to the implementation of these management measures.
- Further studies are required to generate adequate knowledge on lower trophic levels especially the contribution of cyanobacteria, zooplankton, and macroinvertebrates to the biological productivity of the lake.
- On the basis of existing inadequacy of information on the biotic and abiotic environments within Lake Victoria, there is a need to manage the lake resources guided by the precautionary principle, and to continue analysing existing data and monitoring life history indicators.

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Chapter 5
Biodiversity Indicators: Plankton and Macroinvertebrates in Lake Victoria, Selected Satellite Lakes and Rivers

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Abstract Plankton and macroinvertebrates are used as biodiversity indicators on account of their sensitivity to changes in aquatic ecosystems. This chapter assesses the changes in the diversity, abundance and distribution of plankton and macroinvertebrates in the inshore and offshore areas of Lake Victoria, selected satellite lakes and rivers within the lake basin. Samples for both plankton and macroinvertebrates were collected during dry and wet seasons between 2000 and 2006. The results indicated that cyanobacteria were most diverse in both seasons. *Microcystis* spp., *Planktolyngbya* spp. and *Anabaena* spp. were the most dominant cyanophyte species at the sampled sites. The dominant phytoplankton (cyanobacteria) are less digestible and provide poor quality food for the fish; that may have contributed to the reduction or loss of planktivorous haplochromines and tilapiines that once flourished in Lake Victoria. Zooplankton community composition in the lake is dominated by rotifers and cyclopoid copepods, in both inshore and offshore areas. The dominance of cyclopoid copepods is important in the production and sustainability of small fishes and larvae that utilize these organisms as a food base. Macroinvertebrate abundance has shifted from an oligochaete and insect dominated community in 1984 to a community dominated by molluscs. The occurrence of a relatively high

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This chapter is dedicated to Ms. Revania K. Waya, a researcher at TAFIRI, Sota Station, Shirati, who passed away on 25th December 2011.

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abundance of low-oxygen tolerant macroinvertebrate taxa at inshore and offshore stations is an indication of deteriorating water quality water quality conditions due to eutrophication and pollution processes. There is a need for a reduction in nutrient loads and pollutant inputs into the lake in order to ensure the ecosystem health.

5.1 Introduction

Lake Victoria, the second largest lake in the world, and its basin comprise an enormous area of permanent and seasonal freshwaters, including marshes, swamps, floodplains and river systems. All these habitats are characterized by a high diversity of flora and fauna. These water bodies are important reservoirs abound with biodiversity similar to that of Lake Victoria. In the recent history of Lake Victoria, the plankton community has shown some remarkable changes in composition. The first comprehensive studies, which were carried out during the 1950s and 1960s, reported a predominance of large diatoms, particularly from the genera *Melosira* spp. (now called *Aulacoseira* spp.), *Stephanodiscus* spp. and *Nitzschia* spp. (Talling 1966). Cyanobacteria on the other hand, dominated the epilimnion during thermal stratification, while *Ceratium brachycerus* (a dinoflagellate) showed erratic variation. Studies from Verschuren et al. (2002) on changes in the pelagic diatom flora of Lake Victoria over the past 60 years revealed that the lake was stable between 1820 and 1940, with *Cyclostephanos* spp. and *Aulacoseira* spp. making a large proportion of diatoms (80% and 15%, respectively) and *Nitzschia acicularis* absent or too rare to be preserved. The abundance of *Nitzschia acicularis* started to increase between 1940 and early 1960 eventually reaching about 94% of the total diatom abundance.

Apart from the main lake, Lake Victoria basin is endowed with several satellite lakes and rivers, which support livelihood of communities surrounding them. These water bodies are shallow and receive a lot of nutrients from effluents and run-off during rainy seasons, which favour the flourishing of cyanobacteria (Sekadende et al. 2005a). In addition, these satellite lakes and rivers constitute high diversity of zooplankton, mainly crustacean and rotifers (Waya and Chande 2004). The benthic fauna in satellite lakes is the same as that in Lake Victoria, but are characterized by very low species richness and abundance (Wakwabi et al. 2006). Both zooplankton and macroinvertebrates form an important basis of fish production in these waterbodies.

The plankton and macroinvertebrates of Lake Victoria, satellite lakes and rivers can provide useful information on the health of the environment because of their sensitivity to changes in characteristics of the aquatic ecosystems. Species composition with respect to lake habitats has been used as an indicator of environmental degradation. This chapter assesses the changes in the diversity, abundance and distribution of plankton and macroinvertebrates of the Lake Victoria basin, particularly in the inshore (from 0 m to 6 m depth) and offshore (more than 7 m deep) areas of the lake and selected satellite lakes and rivers.

5.2 Methods and Data Analysis

5.2.1 Study Area

The plankton data used in this study were collected in the Tanzania part of Lake Victoria during bottom trawl surveys conducted between 2000 and 2006. In addition, data were also collected from selected satellite lakes and rivers within the Lake Victoria basin, which included Lakes Burigi, Ikimba, Katwe, Malimbe, Kubigena, Kirumi, Mara River and Kyarano dam (Fig. 5.1). Most of these lakes are found on the western side of Lake Victoria and are associated with the Kagera River basin system.

Data for macroinvertebrates were obtained from studies conducted in the three countries bordering the lake in order to obtain a holistic representation of the macroinvertebrate communities. Sampling on the diversity of molluscs in Lake Victoria and a satellite Lake Burigi was carried out from January to April 2002 and March to April 2002 (Mwambungu 2004). Data from Kenyan, Tanzanian and Ugandan waters were obtained on monthly basis from March 1994 to March 1995, except in December 1994 and February 1995 (Muli 2005) and from July to August 2008 in the Tanzanian waters, and from February to March and August to September 2008 in the Ugandan and Tanzanian waters of Lake Victoria.

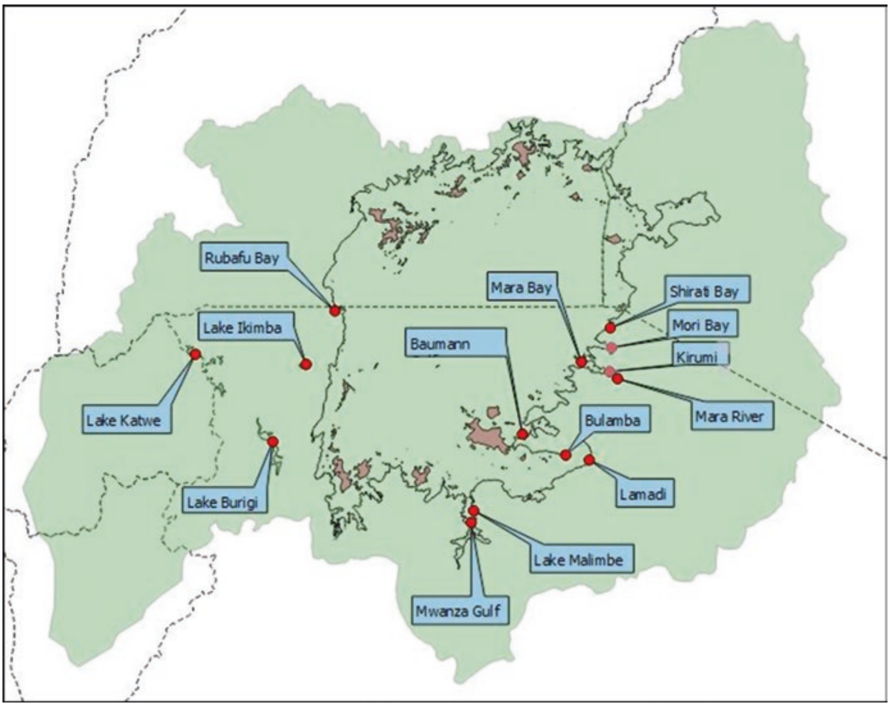

Fig. 5.1 Map of Lake Victoria basin showing the study sites

5.2.2 Phytoplankton Composition and Abundance

Water samples for the analysis of phytoplankton species composition and abundance were collected in the offshore and inshore areas of Lake Victoria between 2000 and 2004 using a one-litre JT-1 Lamotte water sampler. A water sub-sample of 100 ml was preserved with Lugol's solution and formaldehyde (0.7% and 2.5% final concentrations, respectively) and transported to the laboratory at Sota Research Centre in Rorya District, Mara, for analysis. In the laboratory, samples for numerical abundance were allowed to settle for 48 hours to a final volume of 20 ml. This was homogenized by gently shaking the sample bottles by hand to obtain a uniform mixture. A final volume of two millilitres (2 ml) was analyzed for species composition using a Leica inverted microscope (model number 090–135.001) at 400× magnification. Identification of phytoplankton was done based on taxonomic keys by Van Meel (1954), Mosille (1984), and John et al. (2002). All specimens were distributed over at least two transects from the sedimentation chamber and counted. Phytoplankters were counted as numbers of filaments, colonies or cells, depending on the species. At least 10 fields were counted from each sample. The counts made from these samples were used for calculating percentage species composition. The phytoplankton numerical abundance was calculated according to Greenberg et al. (1992) using the formula:-

$$\text{Abundance} = \frac{\text{C} \times \text{At} \times \text{v}}{\text{Af} \times \text{F} \times \text{V} \times \text{Vi}}$$

where, C = number of organisms counted, At = total area of bottom of settling chamber (mm^2), Af = area of field (mm^2), F = number of fields counted, Vi = volume of the sedimented sample, V = volume of the sample observed (2 ml), v = volume of concentrated sample (20 ml).

5.2.3 Zooplankton Composition, Abundance and Biomass

The samples for zooplankton composition and abundance were collected between 2000 and 2005 surveys while those for zooplankton biomass were collected between March 2005 and March 2006. Triplicate zooplankton samples were collected by vertically hauling 65-μm mesh size plankton net (30 cm diameter and one m length) from one metre above the sediment surface. Samples were filtered through a 90-μm mesh plankton sieve (Sethi Standard Test Sieves, Ambala Cantt, India). They were preserved using 4% formaldehyde and transported in cool box to the laboratory at the Sota Research Centre in Rorya District, Mara. In the laboratory, samples were diluted and homogenized by gently shaking the sample bottles by hand. At least 10 ml of each homogenized sample was examined. The identification was done with taxonomic keys and manuals by Ruttner-Kolisko (1974), Korinek (1984), Maas

(1993) and Korovchinsky (1993) as deemed appropriate. Zooplankton species that were identified were counted under a light microscope (model number XSZ-10BN) at x 40 magnification. The data (no./sub-sample) were used to calculate the numbers of zooplankton per sample depending on the split factor and numbers per m^2 according to IFMP (2003–2008) using the formulae:–

$$\text{Abundance}\left(\text{no. sample}^{-1}\right) = \frac{\text{Dilution volume} \times \text{number in a subsample} \times \text{split factor}}{\text{Count volume}}$$

$$\text{Abundance}\left(\text{no. m}^{-2}\right) = \frac{\text{Number per sample}}{\text{Area of net mouth opening}}$$

for a net of 30-cm opening, area = 0.0855 m^2.

For biomass determination, copepod body length was measured from the top of the head to the tip of the furcal rami. Cladocera and rotifers were measured from the top of the head to the tip of the abdomen, excluding spines and other projections. The biomass (mg wet wt m^{-2}) was determined on the basis of the length-weight relationship (Herzig 1984) using the formula:

$$\text{Biomass}\left(mg\ wet\ wt\ \text{m}^{-2}\right) = \left[\frac{\left(4/3^{*}\ \pi\ \text{a}\ \text{b}^2\right)}{10^6}\right] * \text{Numerical abundance of taxa}$$

where π = 3.14, a = 0.5 length and b = 0.5 width.

This method is appropriate for zooplankton species in Lake Victoria because it had previously been applied by Waya and Chande (2004) in the same lake and was found acceptable.

5.2.4 Macroinvertebrates

Sampling for macroinvertebrates was quantitatively done using an Ekman grab with a sampling area of 225 cm^2 (Muli 2005) and 384.16 cm^2 (Mwambungu 2004; Ngupula and Kayanda 2010). The duplicate grab samples collected at a site were combined to form one composite sample. Organisms were separated from sediment using a series of sieves of progressively finer mesh size (20, 2, 1 and 0.5 mm) (Muli 2005) and a net of 500 µm (Ngupula and Kayanda 2010). In the field, specimens were fixed using 10% and 4% formalin (Muli 2005; Ngupula and Kayanda 2010) respectively, and taken to the laboratory for analysis. Mollusca were first anaesthetized using menthol crystals (Muli 2005). In the laboratory, and samples were rinsed with water to remove the formalin and sorted to the lowest taxonomic groups possible, using identification keys by Mandahl-Barth (1958, 1973, 1988) and Brown (1994). The different individuals were then counted and average numbers of organisms per m^2 per station computed. All specimens were preserved in alcohol (70%) for later identification (Muli 2005; Ngupula and Kayanda 2010).

5.2.5 Data Analysis

Data obtained were entered into MS Excel for calculations of abundance and diversity. Zooplankton biomass was analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test for specific differences. The Shannon-Weaver Diversity Index (H′) (Shannon and Weaver 1949) was used to calculate species diversity. The Mann-Whitney (U′) test was used to compare Shannon-Weaver Diversity Indices between seasons. The Quasi-likelihood method was used to test significant differences from different sites; in all cases the level of significance was set at $p < 0.05$.

5.3 Results

5.3.1 Phytoplankton

Offshore Areas

A total of 133 phytoplankton species belonging to 52 different genera were identified in the offshore areas of Lake Victoria during the January to February 2000, December 2000, and July to August 2002 samplings (Table 5.1). A total of 96 and 37 species were recorded in the January to February 2000 and the July to August 2002 sampling sessions, respectively. The cyanobacteria were most diverse in both seasons. The Shannon-Weaver Diversity Index (H′) was high in January to February 2000 ($H' = 0.149$) compared to July to August 2002 ($H' = 0.209$) (Table 5.1). However, the difference was not statistically significant ($U' = 21.0$; $p = 0.095$). The three dominant taxa were Cyanophyta, Chlorophyta and Bacillariophyta while Dinophyta and Euglenophyta were rarely observed.

In the December 2000 sampling, a total of 82 different species belonging to 39 genera were identified, while 16 species were not identified. Common phytoplankton phyla encountered included Cyanophyta, Chlorophyta, Bacillariophyta and Dinophyta. The overall results of species richness show that the phylum Chlorophyta had the highest number of species with a total of 31 species while dinophytes were the least in richness (4 species).

In the January to February 2000 sampling, the abundance of phytoplankton varied from a minimum of 77 to a maximum of 2,450 cells/ml, while in the July to August 2002 sampling, higher numbers were recorded, which ranged from 276 to

Table 5.1 The number of algal species from each algal phylum encountered and unidentified individuals (others) in the five surveyed zones of Lake Victoria – Tanzania

Phyla	Mwanza gulf	Speke gulf	Mara zone	Kagera zone	Emin Pasha gulf
Rainy season (January to February 2000)					
Cyanophyta	15	24	40	15	18
Bacillariophyta	7	10	16	12	5
Chlorophyta	15	12	26	11	11
Dinophyta	0	0	4	0	0
Euglenophyta	4	0	0	1	0
Others (unidentified)	9	13	22	15	10
TOTAL	50	59	108	54	44
H′	0.1802	0.149	0.1	0.134	0.18
Dry season (July to August 2002)					
Cyanophyta	6	11	10	5	–
Bacillariophyta	4	8	6	4	–
Chlorophyta	4	4	10	5	–
TOTAL	14	23	26	14	–
H′	0.252	0.154	0.209	0.223	–

H′ = Shannon-Weaver Diversity Index

5,190 cells/ml. Cyanobacteria dominated the three commonly encountered phyla in almost all stations during both sampling periods (Table 5.1). The total abundance of phytoplankton species was significantly higher ($U' = 315$; $p = 0.009$) during July to August 2002 than the January to February 2000 sampling. Cyanobacteria *Microcystis* spp., *Planktolyngbya* spp. and *Anabaena* spp. were the most dominant cyanophyte species throughout the lake. The diatoms were dominated by *Nitzschia acicularis*.

In the December 2000 sampling, the abundance of phytoplankton at different depths from the offshore stations are presented in Fig. 5.2a–d. There was no discernible pattern in the vertical distribution of phytoplankton. However, cyanobacteria and diatoms were prominent at all depths. The vertical distribution (to 20 m depth) of phytoplankton was assessed at deep stations (Bulamba, Mori, Mwanza and Shirati Bays) only during the January to February 2000 sampling. In general, there were no significant differences in phytoplankton abundance at different depths at these stations.

Inshore Areas

A total of 141 species of phytoplankton belonging to six phyla were identified in inshore areas of Lake Victoria during the period from 2000 to 2004. Results for phytoplankton abundance for each station are presented in Fig. 5.3a–d. In the surface waters, Cyanophyta was generally the most abundant phylum. A total of 37 species belonging to 30 different genera were identified from the sampled stations. Among the five phytoplankton phyla found, Cyanophyta had the highest percentage

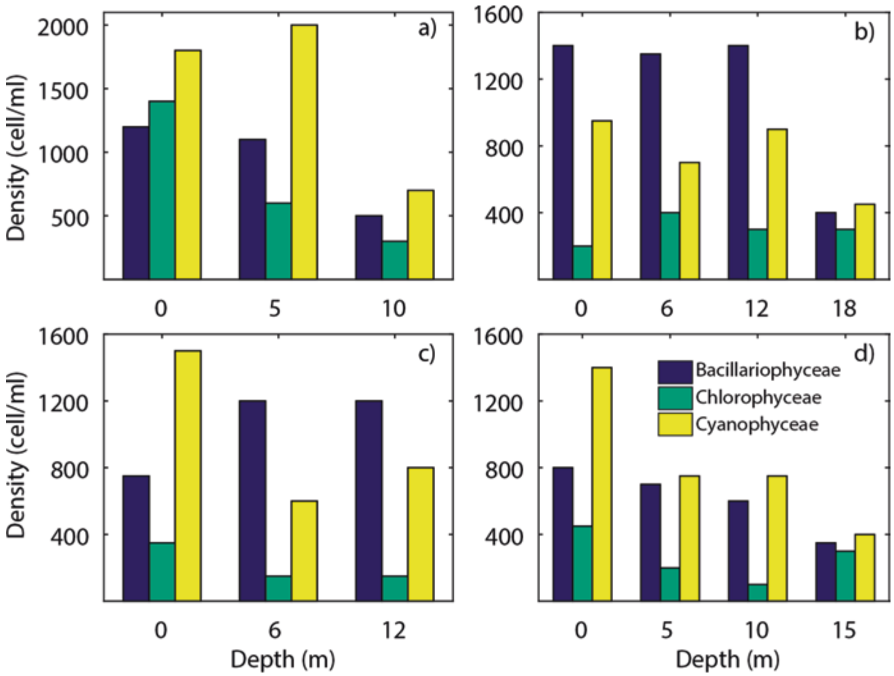

Fig. 5.2 (**a–d**) Numerical abundance and vertical distribution of common groups of phytoplankton in different offshore stations of the Lake Victoria basin (Tanzania, December 2002). *a = Bulamba; b = Mori Bay; c = Shirati Bay; d = Mwanza Gulf* (Data from TAFIRI Unpublished Reports)

composition (59%) in almost all the stations (Fig. 5.3a–d). The occurrence of *Aulacoseira* spp. in Mara Bay, Mori Bay and Lamadi stations (data not shown) was the most interesting realisation in this survey. However, *Romeria* spp., *Nitzschia acicularis* and *Microcystis flos-aquae* were the most abundant species throughout the sampled stations.

Satellite Lakes and Rivers

During the August to September 2002 sampling, a total of 128 species belonging to 54 different genera were identified from phytoplankton samples collected from different satellite lakes of the Lake Victoria basin, which included Lake Burigi, Lake Ikimba, Lake Katwe, Lake Malimbe, Lake Kubigena, Lake Kirumi, Mara River and Kyarano dam. Results for phytoplankton abundance and vertical distribution are presented in Fig. 5.4a–h. The most abundant phytoplankton group in all lakes (except Kyarano dam) was Cyanophyceae. The phytoplankton abundance increased during the rainy season, but the increase was statistically comparable between the seasons ($U' = 17.0$; $p = 0.420$). The most abundant phytoplankton group during the

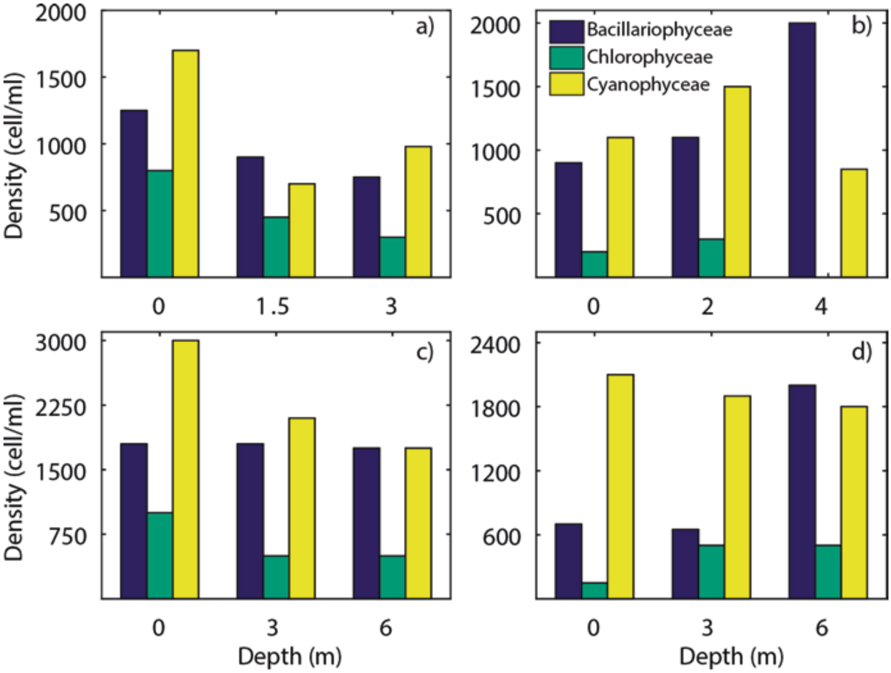

Fig. 5.3 (**a–d**) Vertical distribution of common groups of phytoplankton in different inshore stations of Lake Victoria Basin (August to September 2002). *a = Bawmann Gulf; b = Mara Bay; c = Rubafu Bay; d = Lamadi.* (Data from TAFIRI Unpublished Reports)

dry season was Chlorophyta, which was dominated by *Pediastrum* spp. and *Scenedesmus* spp. The diatom *Aulacoseira* spp., which is now hardly found in the main lake, was abundant in all small water bodies during the dry season. In the rainy season, the Cyanophyta (mainly *Microcystis* spp. and *Planktolyngbya* spp.) was the most abundant group. However, a euglenophyte, *Trachelomonas* sp., was also fairly well represented. Chlorophyta was the most diverse group in both seasons and it was represented by a great number of species (70) followed by Bacillariophyta (19). There was no significant difference between the diversity indices in the two seasons ($U' = 15.0$; $p = 0.690$).

A higher numerical abundance of phytoplankton was observed in May 2004 sampling, when the abundance reached 2,885.77 cells/ml while in the October to November 2003 sampling the abundance was 2,219.6 cells/ml. Among the six-phytoplankton phyla found in May 2004, Cyanophyta was the most abundant group in all the lakes, followed by Chlorophyta and Bacillariophyta. The abundance of Euglenophyta and Dinophyta was low and Chrysophyta had no representative species during this sampling season in the samples for abundance data. In the October to November 2003 sampling, the most abundant phytoplankton group in all lakes was Chlorophyta.

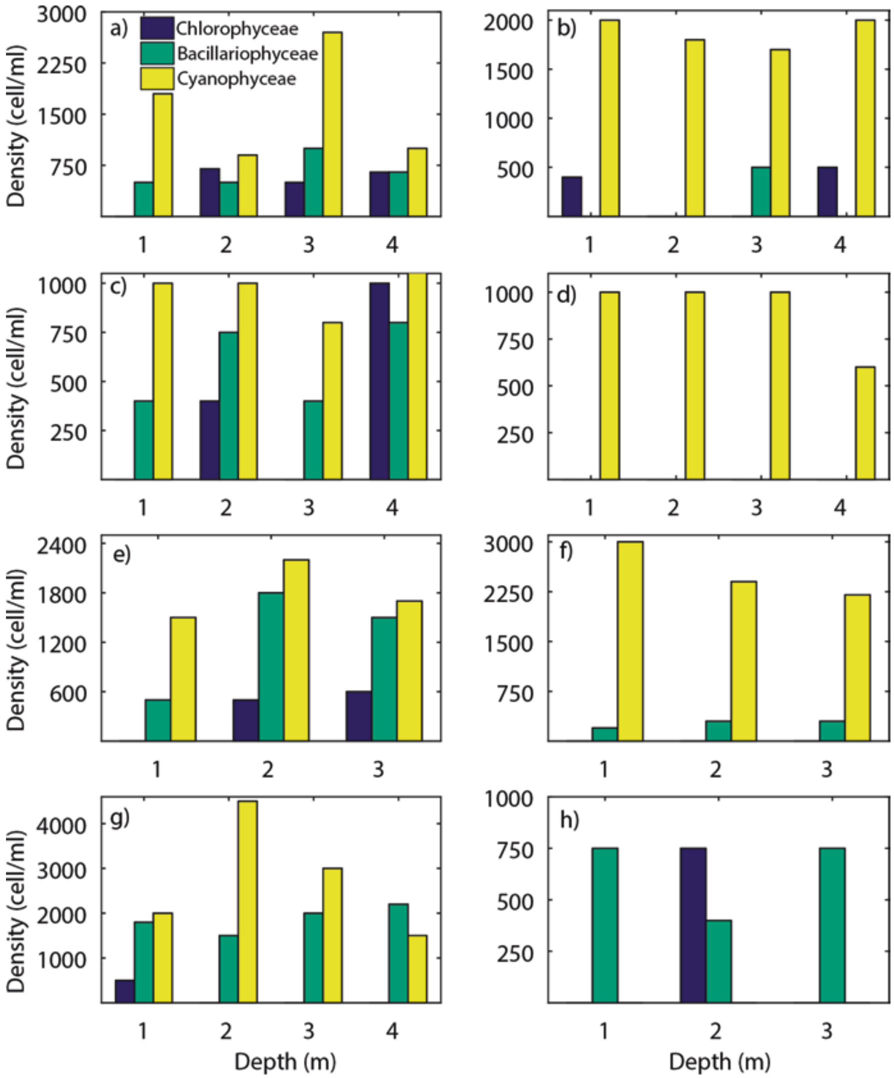

Fig. 5.4 (**a**–**h**) Vertical distribution of common groups of phytoplankton in different satellite lakes of Lake Victoria Basin (August to September 2002). *a = Lake Burigi; b = Lake Katwe; c = Lake Ikimba; d = Lake Malimbe; e = Lake Kubigena; f = Lake Kirumi; g = Mara River; h = Kyarano Dam.* (Data from TAFIRI Unpublished Reports)

5.3.2 Zooplankton

Offshore Areas

The zooplankton taxonomic composition during the January to February 2000, March to April 2000, December 2000, and August and September 2002 samplings in the offshore stations consisted of rotifers and crustaceans, comprising mainly of cladocerans and cyclopoid and calanoid copepods Other planktonic organisms found amongst the zooplankton were the meroplanktonic representatives including larval stages of insects, especially Chaoboridae and the atyid prawns, *Caridina niloticus*. Overall, a total of 20 genera and 32 species of zooplankton were identified from the samples collected. Rotifera comprised the largest number of species (19) followed by Copepoda (8) [cyclopoids (7) and calanoid (1)]. Cladocera contributed only 5 species. The mean zooplankton numerical abundance in Lake Victoria during March to April 2000, August 2002 and September 2002 samplings is shown in Fig. 5.5. The highest number of zooplankton was recorded in December 2000 whereby the number of individual zooplankton reached 745,867 individuals per m^2 and few zooplankton species were recorded for the January and February 2000 sampling with a numerical abundance of 40,072 individuals per m^2. In general, the zooplankton community of Lake Victoria is dominated by rotifers and copepods. Among the copepods, cyclopoid copepods (adults, copepodites and nauplius larvae) were the most common group throughout the study period.

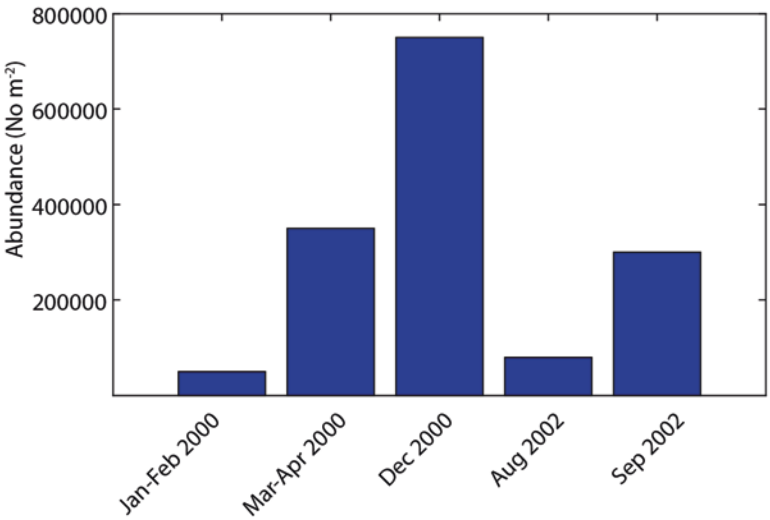

Fig. 5.5 Zooplankton abundance in the offshore areas (≥28 m deep) of Lake Victoria, January to February 2000, March to April 2000, December 2000, August 2002 and September 2002. (Data from TAFIRI Unpublished Reports)

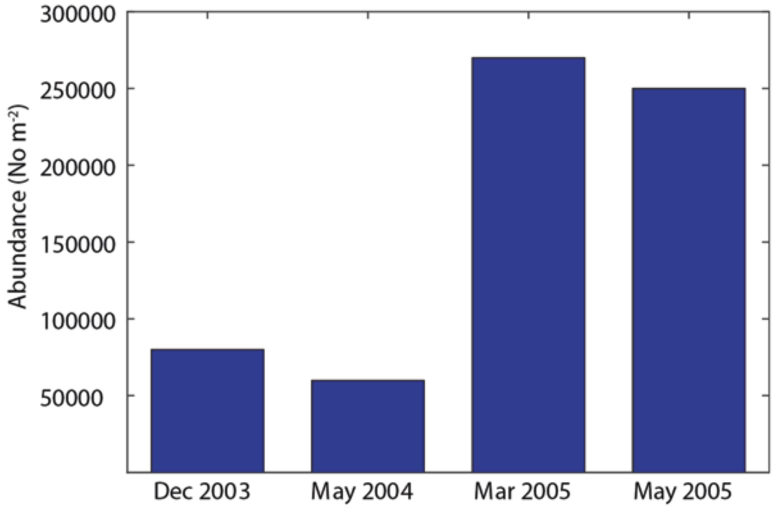

Fig. 5.6 Zooplankton abundance in the inshore areas of Lake Victoria, 2003–2005. (Data from TAFIRI Unpublished Reports)

Inshore Areas

The study on inshore areas was conducted during December 2003 to May 2005. The zooplankton taxonomic composition during the study period consisted of a total of 38 species and 25 genera. Among them, Rotifera contributed the largest number of species (20) followed by Cladocera (9) and Copepoda (9; cyclopoids - 7, calanoid - 1 and harpacticoid - 1).

The total zooplankton numerical abundance is presented in Fig. 5.6. The highest biomass of zooplankton was observed in March 2005 with a mean total abundance of 265,597.12 individuals per m^2 and the lowest abundance was recorded in May 2004. The cyclopoid copepod and its developmental stages (nauplii larvae and copepodites) was the most dominant group throughout the study period.

Zooplankton Biomass

The lowest (31 ± 9 mg wet wt m^{-2}) and the highest biomass (488 ± 148 mg wet wt m^{-2}) were recorded in April 2005 and November 2005, respectively (Fig. 5.7). Zooplankton biomass differed significantly among the different months during the study period ($F = 4.141$, $p < 0.001$). The biomass of zooplankton was significantly higher in November 2005 than in all other months ($p < 0.05$) but had statistically comparable biomass in the months of October 2005 and February 2006 ($p > 0.05$). Similarly, the month of February 2006 had significantly higher zooplankton biomass than all other months ($p < 0.05$) except September 2005, October 2005 and January 2006 ($p > 0.05$). Likewise, the month of October 2005 had significantly

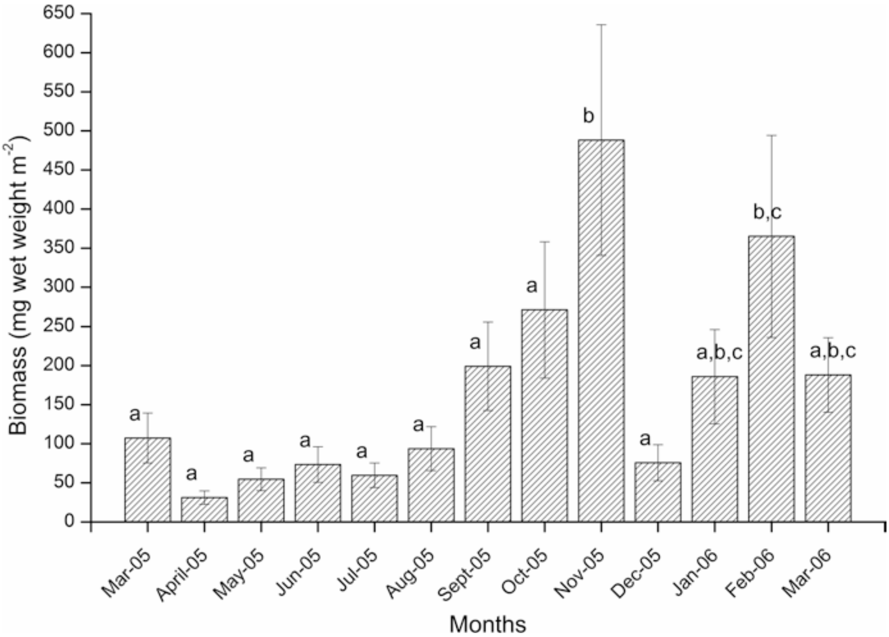

Fig. 5.7 The biomass of zooplankton in Shirati Bay from March 2005 to March 2006. Different letters above the bars indicate sifnificant difference ($p \leq 0.05$). (Redrawn from Waya et al. (2017).

higher biomass than all other months ($p < 0.05$) except September 2005, January 2006 and March 2006 ($p > 0.05$). The month of April 2005 had significantly lower biomass than all other months ($p < 0.05$); while March 2005 had significantly higher biomass than May 2005 ($p = 0.046$) and July 2005 ($p = 0.048$). The months of March 2005, June 2005, August 2005 and December 2005 had statistically comparable biomass ($p > 0.05$). Similarly, May 2005, June 2005, July 2005, August 2005 and December 2005 also had statistically comparable zooplankton biomass ($p > 0.05$).

Generally, the heavy rain season was associated with comparatively higher zooplankton biomass (278 ± 62 mg/m^2) than the light rain season (118 ± 23 mg/m^2) and the dry season (95 ± 17 mg/m^2). Zooplankton biomass depicted significant difference among the three seasons ($F = 7.378$, $p = 0.001$). Significantly higher zooplankton biomass was recorded in heavy rain than light rain ($p = 0.009$) and dry season ($p = 0.001$). However, the light rain and dry seasons recorded statistically comparable zooplankton biomass ($p = 0.899$).

Satellite Lakes and Mara River

Data on taxonomic composition from the satellite lakes in the Lake Victoria basin are presented in Fig. 5.8. The water bodies sampled were Mara River, Kyarano Dam, Kirumi pond, Kubigena oxbow lake, Lake Burigi, Lake Ikimba, Lake Katwe and

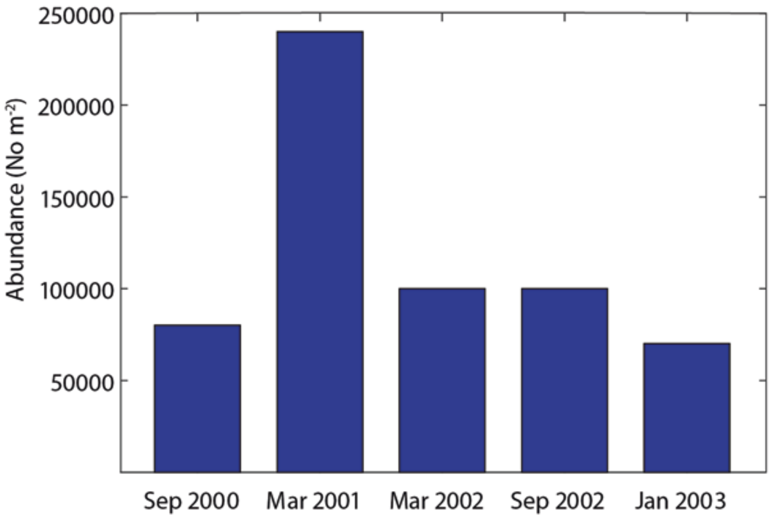

Fig. 5.8 Abundance of zooplankton (total number) in the satellite lakes of the Lake Victoria basin (Data from TAFIRI Unpublished Reports)

Lake Malimbe. During the study period, 33 genera classified into 37 species of zooplankton were identified, among which 23 species were rotifers, six copepod species and eight species of Cladocera. The highest abundance of zooplankton was recorded in March 2001, with a density of 241,685.29 individuals per m^2, while the lowest density was recorded in January 2003, with a density of 64,879.75 individuals per m^2.

Historical Information

Zooplankton species identified during the early studies are shown in Table 5.2. In those studies, different authors identified 17 species of zooplankton. Among the 17 species, five have never been found in recent samples from the Tanzanian part of Lake Victoria (Table 5.2).

5.3.3 Macroinvertebrates

A total of 17 species of molluscs were recorded in the two lakes. The results on species richness, density and the distribution of molluscs in Lakes Victoria and Burigi, as shown in Table 5.3, indicate that there were more molluscan species in Lake Victoria than in Lake Burigi.

In the Kenyan waters, the benthic macroinvertebrates' abundance in the main lake and in Winam gulf was composed mainly of Oligochaeta and Mollusca. Insecta groups contributed a very small portion. In polluted stations, oligochaetes, chironomids

Table 5.2 List of planktonic Crustacea of Lake Victoria from historical data

	Data source/stations/zone				
Species	1	2	3	4	5
Diaphanosoma excisum Sars	+	–	+	–	+
Ceriodaphnia cornuta	+	–		–	+
Ceriodaphnia dubia	+	–		–	–
Moina dubia G. & R.	+	*Brachiata* spp.	+	–	–
Moina micrura	–	–	+	–	+
Daphnia longispina Leydig	+	–	+	–	+
Daphnia lumholtzi Sars	+	–	–	–	+
D. barbata Weltiner	–	–	*Jardinei* Var. *barbata*	–	+
Chydorus sphaericus (O.F. M.)	+	–	–	–	
Bosmina longirostris (O.F.M.)	+	–	*Stuhlmanni*	–	+
Simosa vetulus (O.F.M.)	+	–	*capensis* Sars	–	–
Tropocyclops confinis (Kiefer)	+	–	–	*T. prasinus*	+
Mesocyclops leuckarti Claus	+	–	–	+	+
Thermocyclops neglectus Sars	+	–	–	*Cyclops oithonoides* Sars	+
Thermocyclops schuurmanae Kiefer	+	–	–		–
Thermocyclops emini Mrázek	+	–	–	+	+
Thermodiaptomus galeboides Sars	+	–	–	+	+
Tropodiaptomus stuhlmanni Mzárek	+	–	–	+	–
Total	16	1	7	7	13

+ n = present; – = absent
Sources: (1) Rzóska (1957) – 9 stations, (2) Stuhlmanni (1891) – Mwanza Bay, (3) Weltner (1897) – 4 stations, (4), (5) Waya and Mwambungu (2004)

and gastropods dominated, whilst Ephemeroptera and Bivalvia were the most abundant groups in unpolluted stations.

A study conducted in Tanzanian and Ugandan waters of Lake Victoria by Ngupula and Kayanda (2010) revealed clear trends in macroinvertebrates temporal variations. In the July to August 2008 sampling, the benthic macroinvertebrates of the shallow nearshore, intermediate and deep offshore environments (n = 337) comprised mainly molluscs, insects and worms. Gastropods (44%, 122.97 ± 102.43 ind./m^2) and bivalves (47%, 133.68 ± 110.38 ind./m^2) made up a major part of the density of the macroinvertebrates, constituting 91% of the total abundance. Insects and worms

Table 5.3 Density (No./m^2) and distribution of molluscan species from sediments sampled from Lake Victoria and Lake Burigi

Species	Lake Victoria	Lake Burigi			
	Mara zone	Speke gulf	Mwanza gulf	Bukoba zone	
GASTROPODA					
Viviparidae					
Bellamya unicolor	10	8.45	234	–	–
Bellamya constricta	13	–	–	43	–
Thiaridae					
Cleopatra bulimoides	–	–		–	–
Melanoides tuberculata	182	175	130	17	893
Bithnidae		113			–
Gabbiella humerosa	78		13	–	–
Planorbidae					
Bulinus globosus	–	–	–	–	52
Bulinus forskali	–	–	–	–	26
Bulinus ugandae	9	17	–	–	121
Biomphalaria chaonomphala	17	–	–	–	9
BIVALVIA					
Corbiculidae					
Corbicula africana	173	52	104	329	–
Unionidae					
Caelatura acuminate	–		26	35	–
Caelatura alluaudi	9	9	26	–	–
Caelatura hauttecoeuri	9	74	–	–	–
Caelatura monceti	9	56	–	9	–
Sphaeriidae					
Sphaerium stuhlmanni	–	–	–	89	–
Sphaerium nyanzae	–	–	–	156	–
Eupera parasitica	87	25	–	78	–
Av. ind. per zone	686	1,366	585	756	
Av. ind. per lake	679	1,101			
Shannon-Weaver diversity index	0.8587	0.2973			

Source: Mwambungu (2004)

contributed about 6% (16.67 ± 10.22 ind./m^2) and 3% (7.75 ± 6.34 ind./m^2), respectively (Fig. 5.9a). In the February to March and August to September 2008 surveys benthic macroinvertebrates (n = 156) showed similar composition to that of the July to August 2008 survey with gastropods (57%, 109.73 ± 86.85 ind./m^2) and bivalves (38%, 74.01 ± 42.73 ind./m^2) being the dominant groups. The two groups accounted for 95% of the total abundance, while worms and insects accounted for 3% (5.23 ± 3.21 ind./m^2) and 2% (4.65. ± 3.34 ind./m^2), respectively (Fig. 5.9b).

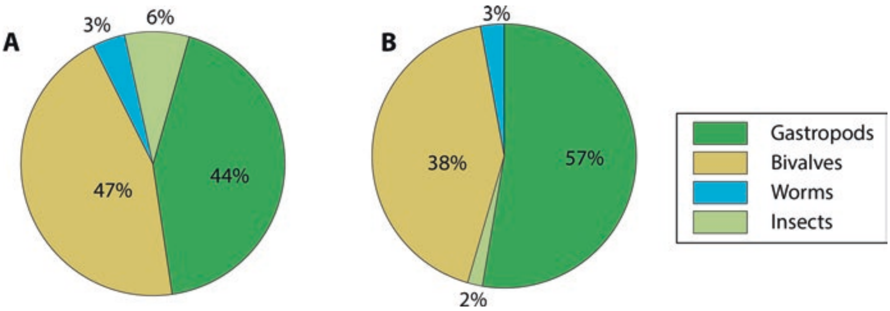

Fig. 5.9 Percentage composition of benthic macroinvertebrate groups in the Tanzanian waters of Lake Victoria during the July to August 2008 survey (**a**) and in the Tanzanian and Ugandan waters conducted during the February to March and August to September 2008 surveys (**b**) (Redrawn from Ngupula and Kayanda 2010)

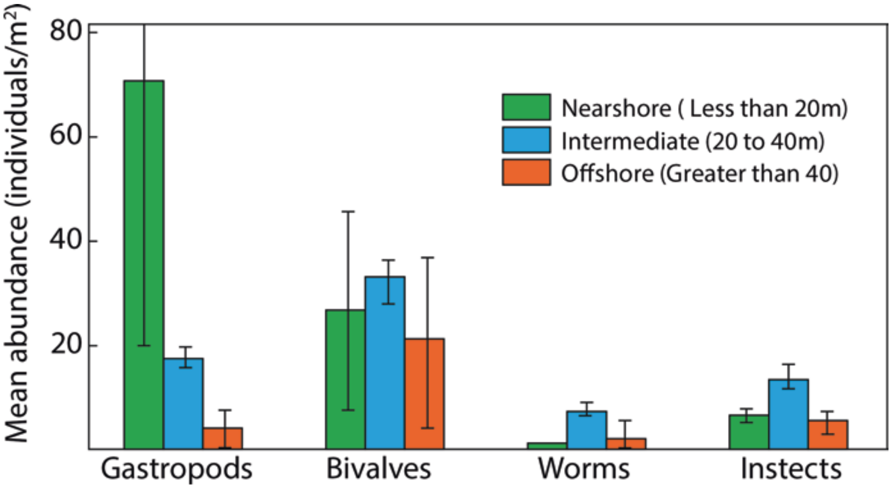

Fig. 5.10 Mean abundance of different macroinvertebrate groups in nearshore, intermediate and deep offshore waters of Lake Victoria. Error bars denote ± SD (Redrawn from Ngupula and Kayanda 2010)

Macroinvertebrates Vertical Distribution

The vertical distribution of macroinvertebrates abundance indicated that, gastropods had a declining trend with increasing water depth, whereas bivalves had a contrasting trend and worm abundance indicated no clear trend. *Chaoborus* spp. was largely encountered in the deep offshore waters, as opposed to most insects, which were abundant in the nearshore waters (Fig. 5.10). Quasi-likelihood showed a significant positive relationship between depth and macroinvertebrate abundance ($p = 0.0014$).

Macroinvertebrates Distribution by Taxon

Molluscs were dominated by two gastropod species, namely *Bellamya unicolor* (Olivier 1804) (Viviparidae) and *Melanoides tuberculata* (Müller 1774) (Thiaridae); and by two families of bivalves (Ngupula and Kayanda 2010). The gastropods, *Bellamya costricta* (Martens 1889) and *B. costulata* (Martens 1892), were less abundant. The *Sphaerium nyanzae* (Smith 1802) (Sphaeridae) and *Coelatura monceti* (Bourguignat 1883) (Unionidae) were both abundant. The other bivalves, *Sphaerium stuhlmanni* (von Martens 1897) (Sphaeridae), and two pelecypods, *Coelatura acuminata* (H. Adams 1866) and *C. alluaudi* (Dautzenberg 1908) (Unionidae), were less abundant. Insects were dominated by Chironomidae and Chaoboridae, while the families Culicidae and Tipulidae were less dominant (Ngupula and Kayanda 2010). Worms were dominated by oligochaetes and turbelarians. Gastropods from the family Planobirbidae, i.e. *Bulinus transversalis* (Martens 1897), *B. ugandae* (Mandahl-Barth 1958) and *Biomphalaria choanomphala* (Martens 1879), were not encountered during the July to August survey in the Tanzanian waters, but were encountered during the February to March and August to September surveys in the Ugandan waters (see Ngupula and Kayanda 2010).

5.4 Discussion

The study found a shift in algal composition from communities dominated by diatoms such as *Aulacoseira* spp. and green algae to cyanobacteria in response to increased phosphorus loading into the lake and a high nitrogen-demand (Sitoki et al. 2012; Gikuma-Njuru et al. 2013). The elimination of *Aulacoseira* spp. was also noted by Kling et al. (2001), which matched with the increased occurrence of a massive cyanobacterial bloom. The shift in phytoplankton species composition is interpreted as an evidence of silicon limitation and increased phosphorus loading which favour cyanobacteria growth. Diatoms and chemical stratigraphy of a sediment core confirmed the disappearance of *Melosira* spp. by the end of 1960s (Hecky 1993). This core study showed that the changes in phytoplankton were accompanied by increased deposition rates of nitrogen (starting in the 1920s) and phosphorus (starting in the 1950s). During the 1960s the biogenic silica deposition started to decrease, causing low concentration of silica in the surface waters. This is believed to have led to the disappearance of *Melosira* spp. from the open waters (Akiyama et al. 1977). Generally, the disappearance of *Melosira* spp. in the 1960s was unique in the recent history of the lake, as the representatives of this genus were present in all the examined sediment intervals deposited over the past 10,000 years (Stager 1984). Thus, the high nitrogen-demand in the lake favours the dominance of cyanobacteria some of which are capable of fixing N_2 to meet their nitrogen requirements.

It should also be noted that the shift in algal composition towards cyanophytes is an indication of changes in the trophic status of the lake, which could have led to eutrophication. The eutrophication conditions favour the growth of cyanobacteria dominated by *Planktolyngbya* spp., *Anabaena* spp. and *Microcystis* spp. Some of the cyanobacteria produce toxins that can be dangerous to aquatic life, human health (Sekadende et al. 2005b; Dittmann et al. 2013; Komárková et al. 2016), and land-based animals that use the water from the lake. Studies show that, cyanobacteria vary both spatially and seasonally in Lake Victoria with the highest concentrations found in bays and during the rainy season, respectively (Haande et al. 2011; Cornelissen et al. 2014). Recent studies also show that *Anabaena* spp. and *Microcystis* spp. dominate in various months and sites (Sekadende et al. 2005b; Haande et al. 2011; Cornelissen et al. 2014), especially in closed bays (Mbonde et al. 2015). Despite the fact that cyanobacteria may bloom all year-round (Luyiga et al. 2015), Lake Victoria has a seasonal succession in species composition of algae with increasing dominance of nitrogen fixing cyanobacteria during the early stratified period followed by non-fixers later in the stratified period and during the deepest mixing period between June and July.

Notwithstanding the shift in algal composition, the phytoplankton species composition from the studies published on the Tanzanian waters of Lake Victoria between 2000 and 2017 (Mbonde et al. 2004, 2015; Machiwa et al. 2005; Sekadende et al. 2005a; Ngupula et al. 2011; Cornelissen et al. 2014, Waya et al. 2017) reveal some similarities with other reports (Cocquyt et al. 1993; Lung'ayia et al. 2000; Hecky et al. 2010; Haande et al. 2011; Sitoki et al. 2012) in the other countries bordering the lake. The major similarity is the predominance of cyanobacteria during thermal stratification of the lake and predominance of diatoms during isothermal mixing of the whole water column. Lake Victoria undergoes thermal stratification during October to March and isothermal mixing in June to August (Lung'ayia et al. 2000; Kling et al. 2001). During thermal stratification, the phytoplankton distribution pattern is a function of the excess density of the organisms. Cyanobacteria have buoyant vesicles that enable them to remain in the surface waters during thermal stratification (Reynolds et al. 1987). This in turn assists the cyanobacteria to trap more sunlight for photosynthesis than other phytoplankton groups; and in addition to that they are more efficient light harvesters than eukaryotic algae, thus explaining their predominance.

The success of some species of cyanobacteria in Lake Victoria especially *Microcystis* spp. and *Anabaena* spp. may also be linked to the high fertility (eutrophication) of the lake (Hecky 1993; Cózar et al. 2012; Schindler 2012). Based on the Carlson and Simpson's (1998) eutrophication guide, lakes containing chlorophyll-*a* concentrations between 20 and 56 μgL^{-1} are deemed eutrophic. Indeed, a recent study by Waya et al. (2017) recorded chlorophyll-*a* ranging from 7.57 ± 0.01 to 69.14 ± 0.87 μgL^{-1} with an average of 22.14 ± 5.14 μgL^{-1}, indicating eutrophic conditions. Eutrophication favours the preferential thriving of cyanobacteria species through a competitive advantage for light as explained above.

In a similar pattern to the main lake, a general pattern of an increasing dominance of N-fixing types (e.g., *Anabaena* spp.) in inshore waters of Lake Victoria has been confirmed by earlier findings (Kling et al. 2001; Gikuma-Njuru and Hecky 2005; Tamatamah et al. 2005). Biological nitrogen fixation has at some period emerged as one of the largest single source of nitrogen during which it accounted for over 80% of the total nitrogen loading to Lake Victoria, exceeding dry atmospheric and rivers inputs (Mugidde et al. 2003).

In satellite lakes of the Kagera River basin, higher species diversity and richness existed during the dry season than the rainy season. Theoretically, in the dry season nutrient fluxes into the lakes are expected to be low due to reduced terrestrial runoff. In less fertile waters the growth rate of phytoplankton is low hence allowing a greater number of species with reasonably similar requirements to coexist than would be found in the more fertile main lake. It is worth noting that, some phytoplankton species that are believed to have gone extinct in the main lake occur in the satellite lakes. For instance, large colonies of *Pediastrum* spp. and *Aulacoseira* spp., which were abundant during the 1960s, are now rarely found in Lake Victoria (Kling et al. 2001) where they exist in inshore areas and some satellite lakes.

The trends in the dynamics of the zooplankton from the studies referred to in this chapter, have shown some changes in both abundance and diversity over the years. However, the community structure of zooplankton still comprised three groups, namely the rotifers and two subclasses of the Crustacea, the Cladocera and Copepoda (Worthington 1931; Rzóska 1957; Akiyama et al. 1977; Mavuti and Litterick 1991; Mwebaza-Ndawula 1994; Waya and Chande 2004; Waya and Mwambungu 2004; Ngupula et al. 2010; Vincent et al. 2012). Prior to the introduction of *L. niloticus* the relative proportions of the major taxa ranked as cyclopoids > calanoids > rotifers and Cladocera in terms of density (No./m^2) in the near shore stations, but in the open water stations the diaptomids became equal or even dominant over cyclopoids (Rzóska 1957).

Historically, the planktonic crustaceans of Lake Victoria have been studied since 1888 when Emin Pasha and F. Stuhlmann collected the first sample in the lake. From that time, different studies have been carried out on the planktonic crustaceans of Lake Victoria but most of them, with the exception of Daday (1910), were dealing with only few species (Daday 1907; Sars 1909; Verestchagin 1915; Delachaux 1917; Gurney 1928). The works that dealt with the general aspects of zooplankton are those by Worthington (1931) and Rzóska (1957). Past historical data show that the zooplankton community of Lake Victoria is dominated by cyclopoid copepods and their developmental stages in terms of abundance and biomass while Rotifera have the highest diversity (Akiyama et al. 1977; Mavuti and Litterick 1991; Mwebaza-Ndawula 1994; Branstrator et al. 1996; Ngupula et al. 2010; Waya et al. 2014). Currently, food availability and predation, among others, seem to be the important factors affecting zooplankton density and biomass in time and space in Lake Victoria (Goudswaard et al. 2006; Budeba and Cowx 2007). The role of zooplankton in secondary productivity is directly related to production of zooplanktivorous fish (e.g., haplochromines, silver cyprinid (dagaa), juvenile stages of the Nile perch and other fish species). Shifts in the relative abundance of zooplankton species can be directly related to availability of fish.

The results have shown a shift in macroinvertebrate abundance from an oligochaete- and insect-dominated community in 1984 to a community dominated by molluscs in 2008 (Mwambungu 2004; Muli 2005; Ngupula and Kayanda 2010). Molluscs, insect larvae and nymphs dominated the benthic fauna of Lake Victoria, while oligochaetes, leeches, nematodes, ostracods and other crustaceans are also present though in minor proportions (Wakwabi et al. 2006). A study conducted by

Ngupula and Kayanda (2010) indicated an increase in the abundance of gastropods and bivalves while that of insects and worms decreased. These results are in agreement with those obtained by Mbahinzireki (1994) and Ligtvoet and Witte (1991) in the lake. This is probably due to the current eutrophication and deoxygenation in the lake (Hecky 1993, Hecky et al. 1994). Since 1986, it has also been noted that the abundance of macroinvertebrates such as *Chaoborus edulis*, the atyid prawn *Caridina nilotica*, oligochaetes, ostracods, molluscs, *Chironomus* spp., nymphs of Anisoptera and Ephemeroptera, have increased compared to the past (Budeba and Cowx 2007; Ngupula and Kayanda 2010) as a result of increasing anoxia in Lake Victoria (Goldschmidt et al. 1993; Njiru et al. 2012).

The obtained differences in macroinvertebrates composition compared to the situation before 1984, are attributable to the different environmental conditions that existed by then and the changes in fish composition after the introduction of Nile perch into the lake. The pre-Nile perch food web in Lake Victoria was dominated by haplochromines, encompassing many trophic specialisations including molluscivory by species like *Synodontis victoriae, Protopterus aethiopicus, Barbus altianalis* (Witte et al. 1995). The molluscs, however appear now to be largely unexploited following the upsurge of the Nile perch resulting in the disappearance of the haplochromine molluscivores and a decline in the abundance of *Protopterus aethiopicus* (Mwambungu 2004).

The results on macroinvertebrates from all the three countries showed that, shallow nearshore environment had the highest abundance than offshore areas. This is attributed to the presence of abundant detritus, and macrophytes, which provide refuges in the shallow nearshore environment. Of the macroinvertebrate groups, gastropods and insects were more abundant in the shallow nearshore waters than bivalves, *Chaoborus* spp. and worms. Bivalves were dominant in the offshore waters, and *Chaoborus* spp. was encountered only in these waters implying variations in feeding habits, tolerance to environmental conditions, species behaviour and competition among different species. The distribution indicates that gastropods and insects are more tolerant to high organic pollution and high turbidity levels, but less tolerant to low oxygen levels, than the bivalves, *Chaoborus* spp. and oligochaetes (Ngupula and Kayanda 2010).

Similar to plankton results, some species of macroinvertebrates obtained highlight the existence of eutrophic conditions in the lake. The oligochaete species obtained, such as *Alma emini*, *Branchiura sowerbyii* and *Tubifex* spp. are known to tolerate low dissolved oxygen concentration (Muli 2005). Tubificidae species such as *Branchiura sowerbyii* and *Tubifex* spp. are known worldwide as indicators of high organic pollution in water bodies. On the other hand, molluscs of the family Ancylidae and insects of the orders Ephemeroptera and Plecoptera are known worldwide to indicate unpolluted water bodies (Muli 2005). Similarly, *M. tuberculata* and *B. unicolor* are tolerant to environmental variations. The absence of the bivalves *Corbicul*a spp. and *Mutela* spp. indicate possible disappearance of these species, although they were once dominant in the lake (Mothersil et al. 1980). However, the dominance of Sphaeridae family among the small bivalves has survived the lake changes because it was reported by Hoogerhoud (1986) in Mwanza

Gulf area. Thus, the existence of rich and diverse benthic macroinvertebrate fauna is expected to provide food for demersal fish species in the lake.

5.5 Conclusions and Recommendations

- The present dominant cyanobacteria species in the lake are less digestible and provide poor quality food for the fish; this may have contributed to the reduction or loss of planktivorous haplochromines and tilapiines that once flourished in Lake Victoria. There is a need for reduction in nutrient loads and pollutant inputs into the lake.
- The zooplankton community in the lake is dominated by rotifers and cyclopoid copepods, in both inshore and offshore areas. This has implications on the production and sustainability of fishes (i.e. *R. argentea,* some haplochromines, larval fishes etc.) that utilize these organisms as a food base. There is need to investigate further on the ecology of the major zooplankton groups and their relative importance as food items of commercial fish species. Moreover, research on the zooplankton community structure should be focused towards developing bioindicators of environmental and water quality.
- The occurrence of a relatively high abundance of low-oxygen tolerant zooplankton taxa at inshore stations is an indication of deteriorating water quality due to eutrophication and pollution processes especially around near-shore areas of the lake. The identification and mapping of sources of pollutants needs to be carried out and control measures (i.e. provision and enforcement of chemical/nutrient standards of effluents to waterways and the lake) must be instituted in order to mitigate the pollution of the lake waters and thereby protect the valuable living resources in the main lake and satellites in the basin.
- Molluscs occur in relatively high abundance in both offshore and inshore areas. This has implications on fisheries production (i.e. juvenile fishes, the lungfish, *Protopterus aethiopicus*, *Synodontis* spp., and *Mormyrus* spp. that use these organisms as a food base). Molluscs and other macroinvertebrates should be thoroughly investigated in terms of batho-spatial distribution, suitability as indicator species of environmental quality and fish food, among others.

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Chapter 6
Stock Assessment of Commercial Fish Species of Lake Victoria

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Abstract The fishery of Lake Victoria is dominated by four major commercial species; the introduced Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*), native dagaa (*Rastrineobola argentea*), and haplochromines. Information on the status of these major fish species is limited because there have been few studies on the exact nature of the stock distribution of the species. As such, it has been difficult to trace the trends and fluctuations in abundance, population structure and composition, which are important in planning fisheries management measures. This chapter provides the current status of the fisheries of these four species by reviewing different trends in biomass, catch rates, catch per unit effort and biological indicators using both fisheries dependent and independent data. The results showed that stock abundance fluctuated over the years, with Nile perch and Nile tilapia abundance considerably reduced mainly due to increased fishing pressure, while dagaa and haplochromines increased over time. Seasonality in environmental factors greatly influenced the distribution and abundance of the species, especially Nile perch. Therefore, concerted efforts are needed to avert a declining trend of Nile perch and Nile tilapia so that their fisheries continue to provide benefits sustainably.

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6.1 Introduction

An understanding of the historical patterns of exploitation of any fishery is a prerequisite for any attempt to carry out stock assessment. What is known about abundance of fish populations and how the stocks respond to exploitation comes primarily from the analysis of catch records (King 2007). Consequently, the management of fisheries relies on the outputs of stock assessment for which a well-organized data collection system is required (Cowx 1996). This can be done either from what is being landed i.e. fisheries dependent data collection or from research surveys i.e. fisheries independent data collection.

As early as 1928 the need to monitor the status of Lake Victoria's fisheries was expressed when gillnet catch per unit of effort (CPUE) started to decline (Lowe-McConnell 1997). Underlying these efforts was the recommended use of 127 mm (5 in.) mesh size gillnets in the early 1930s and the introduction of exotic fish species to boost fish production in the early 1950s for the whole lake. Therefore, *Tilapia melanopleura, T. zillii, O. leucostictus* and *O. niloticus* were introduced in the lake (Welcomme 1968). The Nile perch (*L. niloticus*) was also introduced in the late 1950s and early 1960s (Arunga 1981; Welcomme 1988).

The effect of these introductions to the fishery and ecology of the lake was not immediately realized. Catch rates and the total yield continued to decrease over the following 20 years. With the decrease in catch rates, smaller gillnets of 38–46 mm (1.5–2 in.) were used for harvesting smaller fish. These included *Synodontis* spp., *Schilbe intermedius, Barbus profundus, Brycinus* spp., and the haplochromines in the late 1960s (Marten 1979). Beach seines also increased in the early 1970s to catch the haplochromines, but in doing so they also captured large numbers of spawning and juvenile tilapiines (Marten 1979), hence escalating the effect of the decline in catch rates. During the same period, light fishing for the cyprinid, *R. argentea* (dagaa), also developed. The dagaa light fishery used small mesh sizes (8 to 13 mm), which also harvested juveniles of both haplochromines and tilapiines (Mkumbo 2002).

When the Nile perch established itself in the 1990s, dramatic changes were noted. These changes included the apparent destruction of the endemic haplochromine species flock, which made up about 80% of the fish biomass in the lake in the 1970s (Kudhongania and Cordone 1974) but declined to less than 4% by the early 1990s (Okaronon 2004). Currently, the fishery is dominated by four fish species, two of which were introduced (Nile perch, *L. niloticus* and Nile tilapia *O. niloticus*), the native pelagic cyprinid *R. argentea* (locally referred to as dagaa) and haplochromines which were extirpated by Nile perch in 1980s but have now recovered (Witte et al. 2007).

Changes in species composition, abundance and distribution in any ecosystem have a profound impact on the food web and eventually on the ecosystem in general. Similar changes have occurred in Lake Victoria. The haplochromines encompassed many trophic specializations, these included detritivores, phytoplanktivores, zooplanktivores and the piscivores. There were many species, but now their number has reduced due to changes within the ecosystem. The changes were linked to excessive fishing pressure, increased eutrophication, predation and competition among the species which subsequently shifted the multi-species fishery of the lake to a four-species fishery, *viz*. Nile perch (*L. niloticus*), the silver cyprinid dagaa (*R. argentea*), the introduced tilapiine (*O. niloticus*), and haplochromines. Few studies have been conducted to assess the status of stocks of these four common and other fish species using both fisheries dependent and independent data. As such, it has been difficult to trace the trends and fluctuations in abundance, population structure and composition, which are important for planning management measures. Therefore, this chapter presents the current status of these major fish stocks in Lake Victoria as estimated using both bottom trawl and hydro-acoustic surveys, as well as gillnets for Nile tilapia.

6.2 Methods and Data Analysis

Data for this assessment were obtained from trawl surveys conducted from the year 1996 up to 2014 using R.V. TAFIRI-II and R.V. Explorer. In addition, historical data from Ugandan vessel, R.V. Ibis in 1969/1970 and Tanzanian vessel R.V. Kiboko from 1984 to 1990 were included to build trends in catch rates, spatial changes, length frequencies and mean lengths of various fish species. Data from acoustic surveys from 1999 to 2015 and gillnet surveys from 1999 to 2000 were also included to depict changes in fish stock biomass of major fish species of Lake Victoria and CPUE from commercial catch respectively. These surveys were carried out using standardised methods, and are among the first to provide information to guide the management and development of fisheries of Lake Victoria.

Bottom trawl and gillnet data were analysed using MS Excel and presented as catch rates and CPUE, respectively. Catch rates (kg/h) for each taxon were calculated while CPUE was calculated as catch per species per day. Acoustic data were analysed using Echoview software in which fish density were individually calculated and multiplied by area to give biomass per species. Nile perch density was calculated as number of single targets divided by beam volume after applying the target strength coefficients, while for dagaa and 'others' category, echo integration was used to derive Area Backscattered Coefficients (ABC), which were converted into numerical densities using respective target strength coefficients.

6.3 Results

6.3.1 *Stock Abundance from Trawl Catches*

Temporal Changes of Abundance

Changes with time in the abundance of different fish species using four research vessels for the period of up to year 2000 are presented in Tables 6.1 and 6.2. Trends in the changes cannot be considered because the vessels were not standardized. Table 6.1 gives data on trawl surveys conducted in the Mwanza Gulf using R.V. Kiboko by the Haplochromine Ecology Survey Team (HEST). The results showed that, the catch rates of the haplochromines decreased very steeply from 338.23 kg/h in 1984 to only 3.99 kg/h in 1987. In 1988, the catch rate was almost negligible, whereby only 0.27 kg/h was recorded (Table 6.1). While the catches of the haplochromines were decreasing, those of the Nile perch were increasing, reflecting a predator-prey pattern. The catch rates of *L. niloticus* increased very steeply from 39.10 kg/h in 1984 to 126.56 kg/h in 1987, but thereafter, the catches decreased with time to 66.54 kg/h in 1990. The other fish species showed a decreasing trend with time.

Table 6.2 presents catches of different fish species using three research vessels; Ibis, R.V. TAFIRI II, and R.V. Lake Victoria Explorer under East African Freshwater Research Organization (EAFFRO), the Lake Victoria Environmental Management Project (LVEMP) and the Lake Victoria Fisheries Research Project (LVFRP I and II) respectively. The Nile perch dominated the catches from 1989 to 2000; but haplochromines predominated before this time. In 1969/1970, the haplochromine catch was 450.2 kg/h and constituted 71% of the total catch. Twenty-four other species were caught but the Nile perch catch was negligible (1.0 kg/h). The contribution of the other species, e.g. *O. esculentus, Bagrus docmak, C. gariepinus, Protopterus aethiopicus* and *Synodontis victoriae,* was more than 10 kg/h of the catches.

Table 6.1 Fish species catch rates (kg/h) from trawl catches in Mwanza Gulf using R.V. Kiboko during 1984–1990

Species	1984	1985	1986	1987	1988	1989	1990
Lates niloticus	39.10	62.28	101.40	126.56	77.10	86.10	66.54
Bagrus docmak	1.36	5.82	3.23	0.61	0.19	0.06	0
Clarias gariepinus	1.71	2.64	2.68	3.01	1.59	1.11	0.34
Haplochromines	338.23	214.27	61.09	3.99	0.27	0.50	1.27
Protopterus aethiopicus	26.77	16.32	5.37	2.30	4.60	0.81	0.99
Schilbe intermedius	0.61	0.69	0.88	0.86	0.25	0.16	0.26
*Tilapia*sp.	5.24	5.79	5.20	3.45	1.39	2.22	1.34

Source of data: HEST/TAFIRI (1984–1990)

Table 6.2 Fish species catch rates (kg/h) sampled by the three research vessels: Ibis, R.V. TAFIRI II and R.V. Victoria Explorer during 1969/70–1999/2000

	Ibis	TAFIRI II	Victoria Explorer	
Species	1969/1970	1995	1996	1999/2000
Haplochromines	450.15	0	10.44	32.71
Oreochromis esculentus	17.46	0	0	0
O. variabilis	0.68	0	0	0
O. niloticus	2.73	0	3.37	4.86
O. leucostictus	0	0	0	0
Tilapia zillii	0.13	0	0	0
Bagrus docmak	29.38	0	0	0.18
Clarias gariepinus	20.95	0	0	0.73
Xenoclarias eupogon	0.26	0	0	0
Protopterus aethiopicus	11.88	0	0	2.71
Lates niloticus	1.00	191.20	279.90	249.11
Synodontis victoriae	12.51	0	0	0.18
S. afrofischeri	0.10	0	0	0.04
Barbus profundus	0	0	0	0.31
B. altianalis	0.32	0	0	0.23
Labeo victorianus	0.17	0	0	0.02
Mormyrus kannume	0.31	0	0	0
Schilbe intermedius	0.63	0	0.89	1.67
Brycinus spp.	0	0	11.92	0.54
Afromastacembalus frenatus	0	0	0	0
Gnathonemus longibarbus	0	0	0	0
Rastrineobola argentea	0	0	0	2.80
Caridina niloticus	0	0	0	0.01
Total	548.66	191.2	306.53	296.1

Source of data: EAFFRO, LVEMP, LVFRP

Furthermore, surveys using R.V. TAFIRI II carried out in 1995 and 1996 showed that Nile perch catch rates increased from 191 kg/h (almost 100% of the catch) in 1995 to 279.9 kg/h (91%) in 1996. Other species in the catch included haplochromines, *S. intermedius* and *O. niloticus,* but their contribution was minor (Table 6.2). The Nile perch contributed 91.6% of the catches (249.11 kg/h) during the 1999/2000 survey using R.V. Victoria Explorer, while haplochromines had reappeared and became an important component of the catch (32.7 kg/h representing 5.7% of the total catch). Trends in the catch composition of major fish species currently indicate a decline in the composition of the Nile perch from over 90% in 2003 to 70% in 2013, while haplochromines and other species showed an increase in composition from 4.3% and 1.5% in 2003 to 15.15% and 13.36% in 2013, respectively.

The trends of catch rates with time for the Nile perch (predator) and the haplochromines (important prey) are presented in Fig. 6.1a, b. Generally, there was an inverse relationship; as the Nile perch increased the haplochromines decreased. For

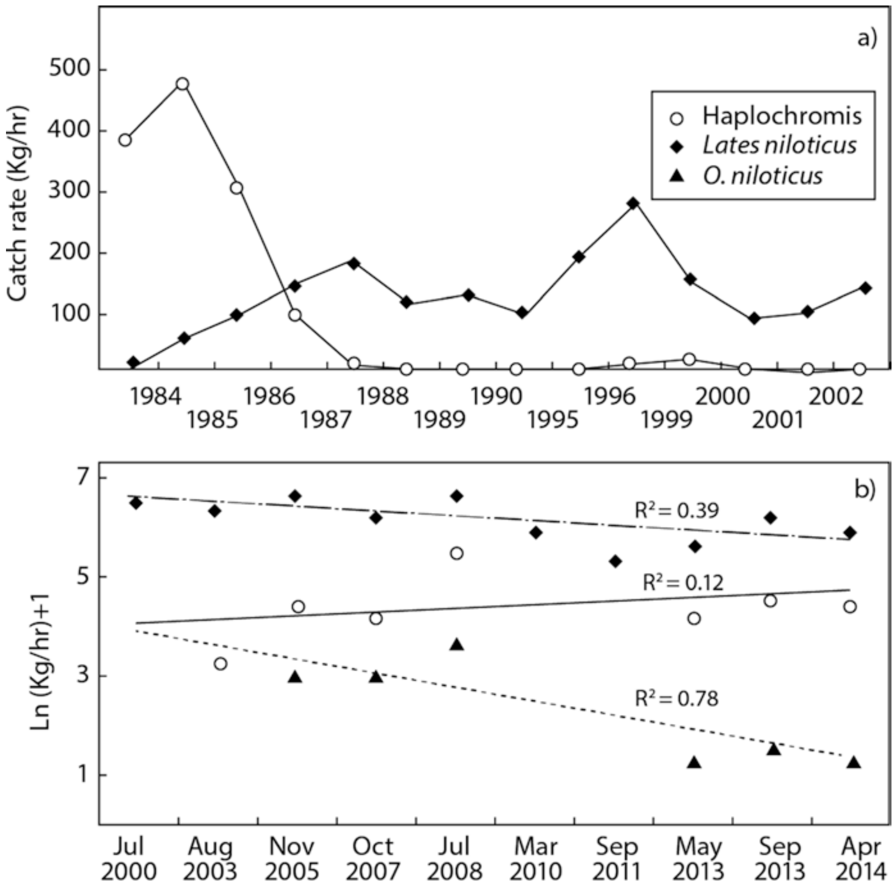

Fig. 6.1 (**a**) Trends of catch rates (kg/h) of *L. niloticus* and haplochromines during 1969/1970–2002 from trawl catches of standardized (Horse Power) research vessels; (**b**) Major species mean catch rates per year since 2000 (Data from TAFIRI Unpublished Reports)

example, during 1969/1970 the catch rate of the haplochromines was highest at 375.17 kg/h and the Nile perch was the least at 0.83 kg/h, showing a typical predator–prey relationship. Thereafter the catch rate of the Nile perch increased and reached a peak in 1987 (180.86 kg/h) while that of the haplochromines decreased to only 5.71 kg/h in the same year.

Between 1988 and 1990, the abundance of the Nile perch decreased and ranged from 95.0 kg/h to 110.14 kg/h. The abundance of the haplochromines remained extremely negligible up to 1996 when there was a recovery, recording 10.4 kg/h. The abundance of the haplochromines showed even a higher recovery in 1999 whereby 32.7 kg/h was recorded, but this decreased thereafter. Moreover, during the Implementation of Fisheries Management Plan (IFMP) from 2003 to 2008, the catch rate for haplochromines continued to remain extremely low with a fluctuating pattern. However, the mean catch rate for haplochromines was 31.16 ± 3.55 kg/h from the 2014 survey. The highest catch rate was recorded in strata I and II with 36.14 ± 13.34 kg/hour and 37.07 ± 5.13 kg/h respectively. The highest catch of 132 kg/h was recorded in stratum I at Rubafu bay in Bukoba compared to the last survey of September 2013 where the highest catch rate was 111.1 kg/h, which was recorded in stratum II at Musira Island. Like the survey conducted in 2013, the western side of the lake had higher catches of Haplochromines than the eastern side.

For the April 2014 survey, the mean catch rate for *L. niloticus* was 137.48 ± 16.79 kg/h compared to 185.96 ± 8.68 kg/h recorded in September 2013 and 110.82 ± 6.69 kg/h from the May 2013 survey. But when compared to the last trawl survey conducted under the IFMP project in July 2008, which had a mean catch rate of 296.2 ± 17.74 kg/h, there was a decrease of 158.5 kg/h. The mean catch rates of Nile perch across depth strata increased with depth strata and reached the highest level at a depth ranging from 30–40 m before it decreased.

6.3.2 Spatial Changes of Abundance

Trawl surveys to estimate abundance (CPUE) of different fish species were carried out by R.V. TAFIRI II from 2000 to 2002 under the LVEMP in different areas within Tanzania (Fig. 6.2), and the results are presented in Tables 6.3, 6.4 and 6.5. The results show that different fish species are distributed differently in different areas, but *L. niloticus, O. niloticus* and the haplochromines were the most common fish in many areas. *L. niloticus* was the most abundant with the highest catch rate of 197.5 kg/h recorded in Mara bay in 2000; while the least catch rate (40.4 kg/h) was recorded at Shirati bay. During 2001, the highest abundance was recorded at Bunda hills (227.0 kg/h) followed by Bulamba (170.67 kg/h), both of which are within the Speke Gulf; and the least was recorded at Magu bay (24.0 kg/h). Bawmann Gulf had the highest abundance during 2002 (481.07 kg/h) followed by Bulamba in the Speke Gulf (173.59 kg/h).

O. niloticus was highly abundant at Nyamirembe during 2000 and 2001 whereby 63.2 kg/h and 37.07 kg/h were recorded respectively; while the species was most abundant (47.82 kg/h) at Shirati bay in 2002. The haplochromines were observed at each site except at Baumann Gulf where none was encountered during the entire sampling period. The catch rates in other areas ranged from 0.1 kg/h to 10.09 kg/h.

The batho-spatial distribution of the Nile perch in Lake Victoria was investigated by the LVFRP and covered three zones (A, B, and C; Fig. 6.3). Cowx (2005) reported variations of catch rates with depth in Zone A as minimal at between 200 and 250 kg/h, while in Zone B catch rates remained higher than 300 kg/h at depths between 10 and 40 m. The Nile perch in Zone C occurred in the greatest densities in waters between 20 and 40 m deep (Fig. 6.4). Shallower waters in Zone C were characterised by lower Nile perch densities. Cowx (2005) associated reduced abundance of the Nile perch in the deep waters with the presence of a thermocline at depths between 25 and 35 m. The breakdown of this thermocline during the rainy seasons led to an improvement in the catch rates (Cowx 2005). The catch rates were converted

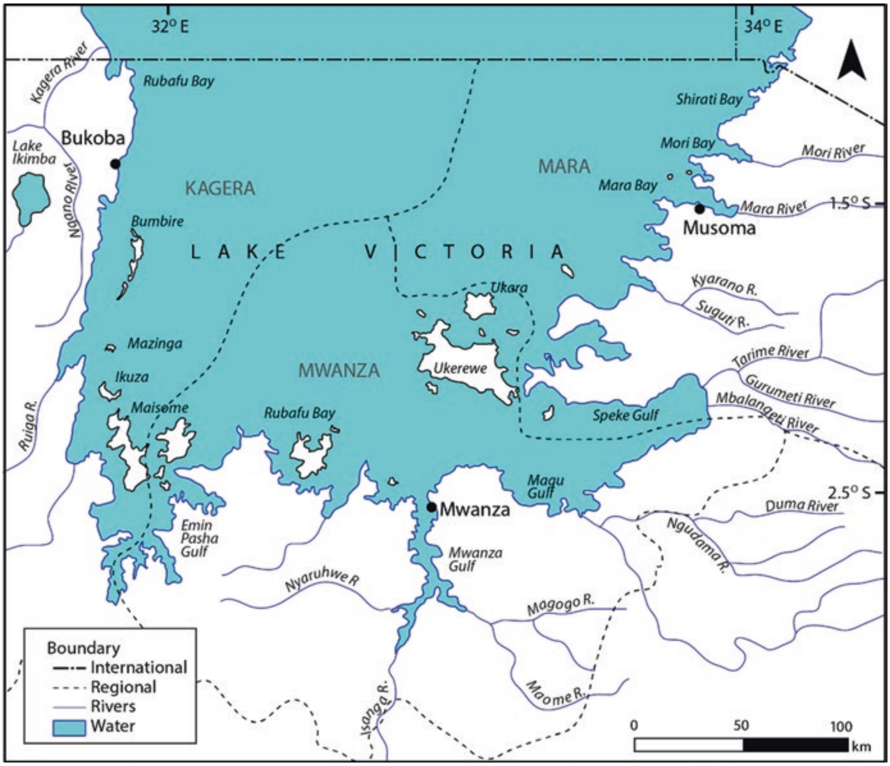

Fig. 6.2 Map of Lake Victoria showing sampling stations

to biomass estimates (Cowx 2005), which revealed that Zone A has a markedly higher standing stock biomass of Nile perch than elsewhere (Table 6.6).

The population structure of Nile perch is presented in (Figs. 6.5 and 6.6). Estimates of Nile perch population structure by measurement of specimens retained by net hauls indicate that the population skewed to the juveniles, whereby majority of Nile perch caught were below 20 cm TL (Fig. 6.6) with mean size ranging from 11.44 cm TL to 19.0 cm TL. These results indicate that the population of Nile perch continues to be dominated by juvenile fish (Mlaponi et al. 2009). In addition, this shows that the number of big fish is still low, which can compromise ability of Nile perch stock to replenish itself. Although Nile perch has high fecundity (Mlaponi 2011) the situation calls for urgent management action. It is recommended that these few large Nile perch should be protected, since they are spawners, so as to regenerate the population of Nile perch.

The frequency distribution of the Nile perch during 2002–2005 indicated that the mean size of the Nile perch ranged from 32.37 cm TL in 2002 to 11.80 cm TL in 2005. This shows a progressive decline of the mean size of the Nile perch from the lake (Fig. 6.5).

Table 6.3 Catch rates (kg/h) of different fish species from R.V. TAFIRI II catches from different sites of Lake Victoria during 2000

Species	Sites											
	Karumo	Bulamba	Ramadi	Magu bay	Bunda hills	Mara bay	Mori bay	Shirati bay	Baumann Gulf	Luchiri bay	Chato bay	Nyamirembe
Lates niloticus	69.3	89.6	61.6	85.8	119.5	197.5	78.5	40.4	83.3	110.0	47.6	77.3
Oreochromis niloticus	0	2.7	4.2	0.11	1.9	1.6	9.7	4.2	35.5	1.7	9.8	63.2
Haplochromines	1.7	0.9	7.1	2.3	0.1	1.1	3.5	0.8	0	2.0	0.1	0.2
Schilbe intermedius	0	1.1	2.3	0.2	0.3	0	2.91	0	0	0.23	0	0.02
Synodontis afrofischeri	0.14	0	0	0	0	0	0	0	0	0.04	0.13	0
Synodontis victoriae	0.01	0.03	0	0.06	0	0	0	0	0	0	0.22	0
Brycinus sadleri	0.07	0	1.90	0.5	0.13	0	0	0	0	0	0	0
Protopterus aethiopicus	202.0	0	0.38	3.0	0	0	0	0	19.0	5.75	0	0
Barbus sp.	0.08	0	0	0	0	0	0	0	0	0	0	0
Bagrus docmak	0.40	0	0	2.0	1.0	0	0	0	0	0	0	0
Clarias gariepinus	0	0	1.17	2.83	0	0	0	0	2.0	0	0.25	2.34
Labeo victorianus	0	0.02	0.02	0	0	0	0	0	0	0	0	0

Source: LVEMP survey data

Table 6.4 Catch rates (kg/h) of different fish species from R.V. TAFIRI II catches from different sites of Lake Victoria during 2001

Species	Sites									
	KR	BL	RM	MG	BH	SB	RB	LB	CB	NR
Lates niloticus	102	171	94	24	227	94	31	44	95	28
Oreochromis niloticus	0	0.7	0	0	8.0	0	1.0	0	0	37
Haplochromines	1.0	1.1	6.1	3.0	3.0	6.1	3.0	1.0	0.1	0.2
Schilbe intermedius	0	5.5	0	1.0	0	0	0	0	0	0
Synodontis afrofischeri	0	0.3	0	0	0	0	0	3.0	0	0
S. victoriae	0	0.4	0	0	0	0	0	0	11	0
Brycinus sadleri	0	0.4	5.4	0	13	5.4	0	0	0	0
B. jacksonii	0	0.1	2.3	0	5.0	2.3	0	0	0	0
Protopterus aethiopicus	69	0	8.0	5.0	0	0	0	0	0	0
Bagrus docmak	0	0	0.0	4.0	0	0.0	0	0	0	0
Clarias gariepinus	0	0	0	1.0	0	0	4.0	0	0	0

Key: *KR* Karumo, *BL* Bulamba, *RM,* Ramadi, *MG*, Magu bay, *BH*, Bunda hills, *SB*, Shirati bay, *RB*, Rubafu bay, *LB*, Luchiri bay, *CB*, Chato bay, *NR*, Nyamirembe. (Source: LVEMP survey data)

Table 6.5 Catch rates (kg/h) of different fish species from R.V. TAFIRI II catches from different sites of Lake Victoria during 2002

Species	Sites									
	KR	BL	RM	MB	RB	OB	SB	RB	CB	BG
L. niloticus	117	174	17	21	98	167	76	136	98	481
O. niloticus	0.8	3.5	4.7	0.0	10	0.0	48	5.4	20	20
Haplochromines	1.3	2.5	10	3.5	0.1	0.8	0.5	4.3	1.2	0.0
Schilbe intermedius	0.2	0.7	0.2	0.6	0.2	0.0	2.0	0.0	0.0	0.0
Synodontis afrofischeri	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.5	0.0
S. victoriae	0.1	0.1	6.8	0.2	0.0	0.0	0.0	0.0	0.2	0.0
Brycinus sadleri	0.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B. jacksonii	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Protopterus aethiopicus	4.2	0.0	0.0	21	0.0	0.0	0.0	0.0	0.0	2.0
Bagrus docmak	0.1	0.0	0.3	0.6	0.0	0.0	0.7	0.0	0.0	0.0
Clarias gariepinus	0.0	0.0	0.0	6.0	17	0.0	0.0	1.8	0.0	0.0
Barbus sp.	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.3	0.0	0.0
Tilapia zillii	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0

Key: *KR*, Karumo, *BL*, Bulamba, *RM*, Ramadi, *MB*, Magu bay, RB, Mara bay, *OB*, Mori bay, *SB*, Shirati bay, *RB*, Rubafu bay, *CB*, Chato bay and *BG*, Baumann Gulf. (Source: LVEMP survey data)

The population structure of Nile perch caught during the 2006–2014 surveys ranged from 2 cm to 167 cm TL with a mean length ranging from 11.44 cm TL to 19.70 cm TL (Fig. 6.6). On top of that, only five specimens of more than 100 cm TL were recorded during the period of 2013–2014, while the weight of the fishes ranged between 16.44% and 33.14% of the fish above 50 cm TL, which is the lower limit of slot size. This means that the processing factories were supposed to receive only 16.44% to 33.14% by weight of the total landings of Nile perch within the mentioned

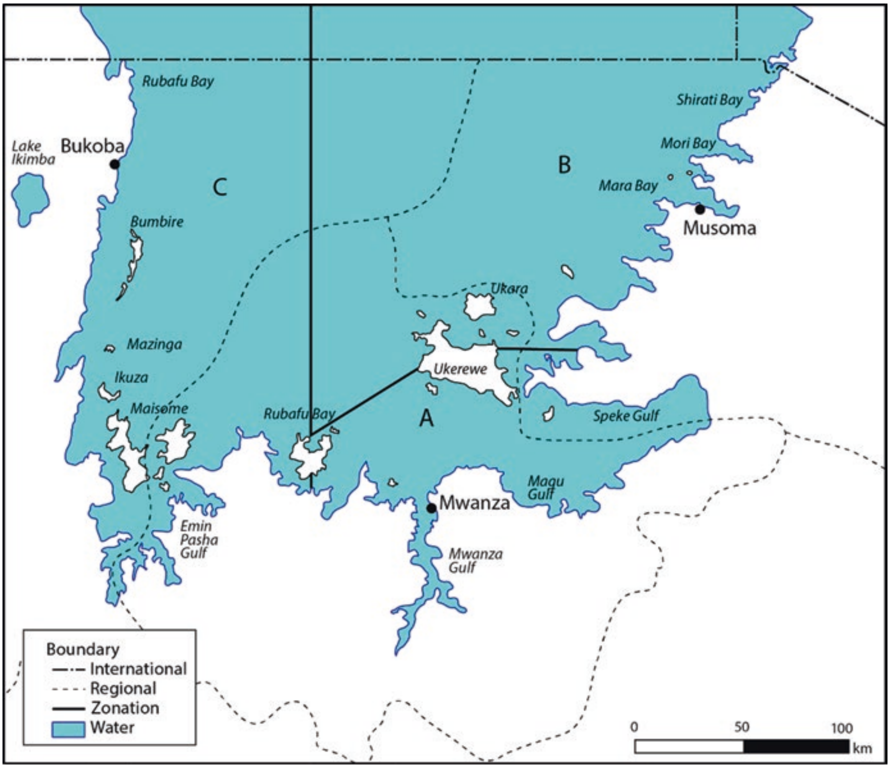

Fig. 6.3 Map showing zonation of Lake Victoria for the trawl surveys (Redrawn from Cowx 2005)

period. Individual populations of the large sized Nile perch, which are targeted by fishermen within a stock are in different circumstances, at risk of becoming extinct by excessive fishing pressure (Figs. 6.5 and 6.6). The population mean size of Nile perch for the period of 2002–2014 dropped from 32.37 cm TL to 17.9 cm TL with the lowest average size at 11.44 cm TL in 2013. Moreover, the composition of the Nile perch with TL >50 cm, which is the lower limit of the slot size, decreased progressively from 19.91% in 2002 to 2.23% in 2014. The lowest contribution (1.65%) was recorded in 2008. Nile perch have high fecundity, which help them to bounce back from exploitation and other environmental pressures. This means that Nile perch can be more resilient to changes in its habitats, such as that caused by climate change, if there is a healthy population with a sufficient number of mature females. It is therefore important to preserve all the habitats that affect its life cycle and to practise responsible fisheries for sustainability.

The Nile perch size distribution exhibited variability with depth of the water column, whereby juvenile fish <20 cm TL dominated the catches in shallow waters (< 30 m deep) (Fig. 6.7). The fish with TL between 15 and 50 cm were distributed predominantly in deeper waters. Larger fish also contributed more to the catches in

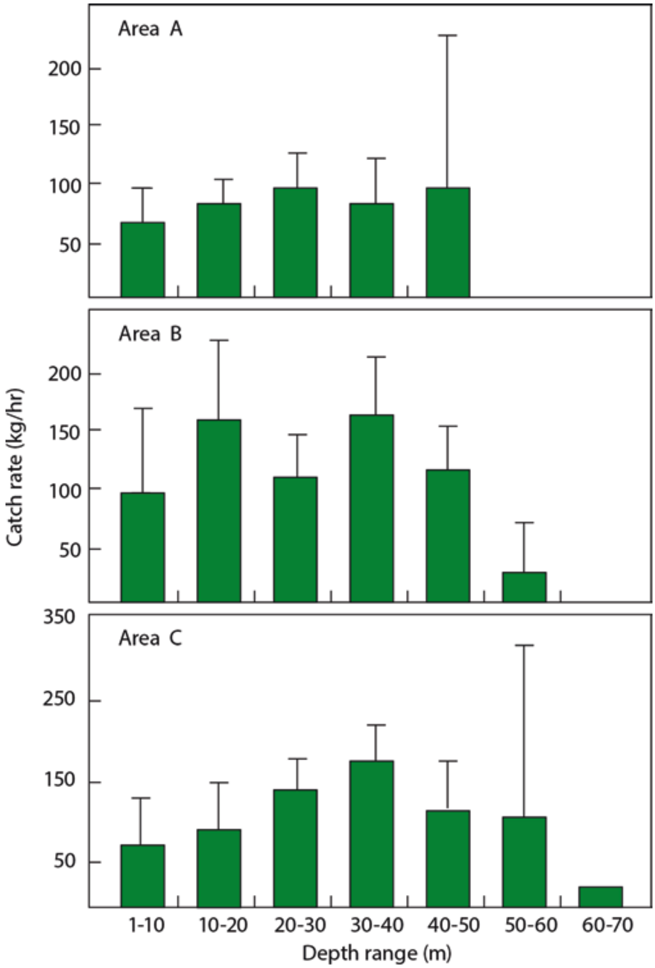

Fig. 6.4 Variation in bottom trawling catch rates (kg/h) of the Nile perch with depth in different zones of the Tanzanian sector of Lake Victoria (Redrawn from Cowx 2005)

Table 6.6 Mean standing stock (t/km^2; mean ± 95% confidence limits) by zone for fish caught during bottom trawl surveys in Lake Victoria between January 1999 and September 2000

Zone / Species	*Lates niloticus*	*Oreochromis niloticus*	Haplochromines
Zone A	12.36 ± 1.96	0.14 ± 0.168	1.33 ± 0.18
Zone B	9.56 ± 1.86	0.16 ± 0.18	0.52 ± 0.20
Zone C	9.80 ± 1.96	0.80 ± 0.20	0.02 ± 0.18
All zones	10.18 ± 1.04	0.14 ± 0.16	0.94 ± 0.28

Source: Cowx (2005)

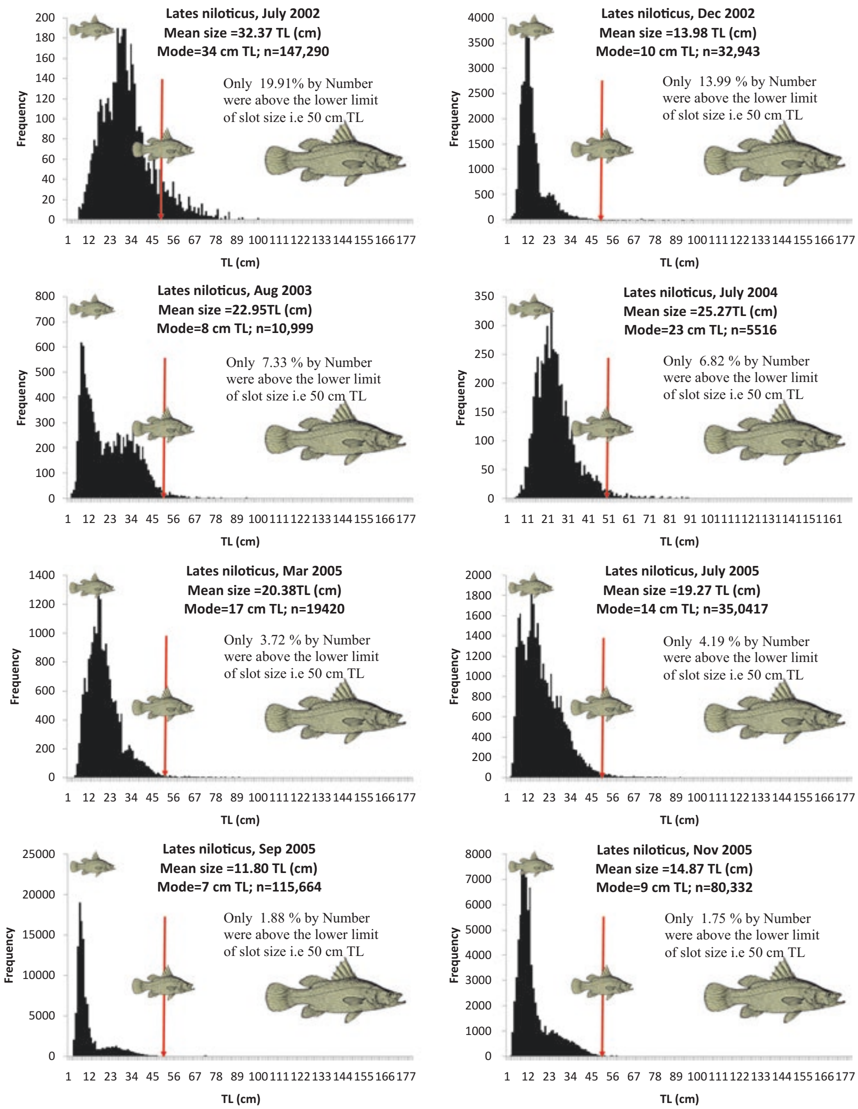

Fig. 6.5 The population structure of Nile perch from bottom trawling collected during 2002–2005 surveys

deeper waters (Fig. 6.7), pointing to a possibility that large Nile perch occupy deeper, offshore waters of Lake Victoria.

Time series data indicate that there is no change in mean length except for 2002, which had the highest mean length (Fig. 6.8). This may be a result of the export bans that were imposed at various times between 1997 and 2000, which led to a reduction

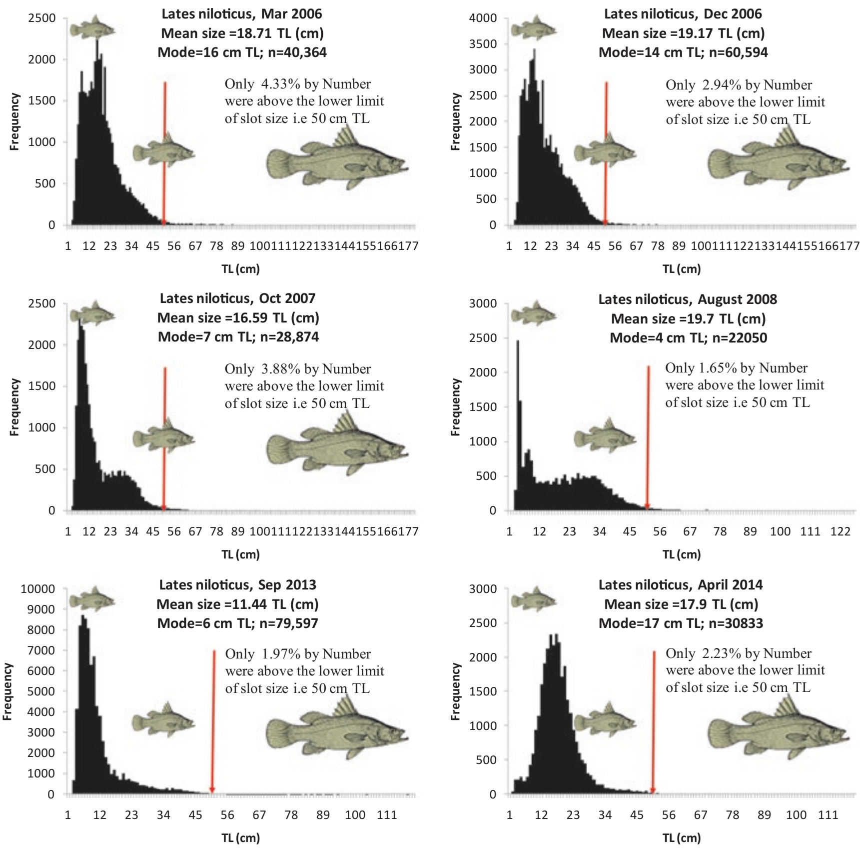

Fig. 6.6 The population structure of Nile perch from bottom trawling collected during 2006 to 2014 surveys

in the total catch and, presumably, a decrease in fishing effort. This increase in mean length was not sustained as it fell back to about 18 cm by 2007.

The experimental bottom trawl surveys by LVFRP also covered other fish species. Catch rates of *O. niloticus* varied between zones, with fewer fish reported in waters deeper than 20 m (Fig. 6.9). This is consistent with the behaviour of the Nile tilapia, which prefers a shallow water habitat (Cowx 2005). Haplochromines were found in water of all depths with their abundance declining with depth (Fig. 6.9). Cowx (2005) reported that *O. niloticus* was more prevalent in the western and central zones, while the opposite was found for haplochromines, which were relatively more abundant in Zone A.

Nevertheless, Cowx (2005) reported a negative relationship between the proportion of larger fish in the area (e.g., Mwanza) and the fishing intensity. Trawl catch samples revealed a high proportion of immature fish (Fig. 6.10). The author further suggested that the lack of large mature fish indicates (i) the selective nature of the

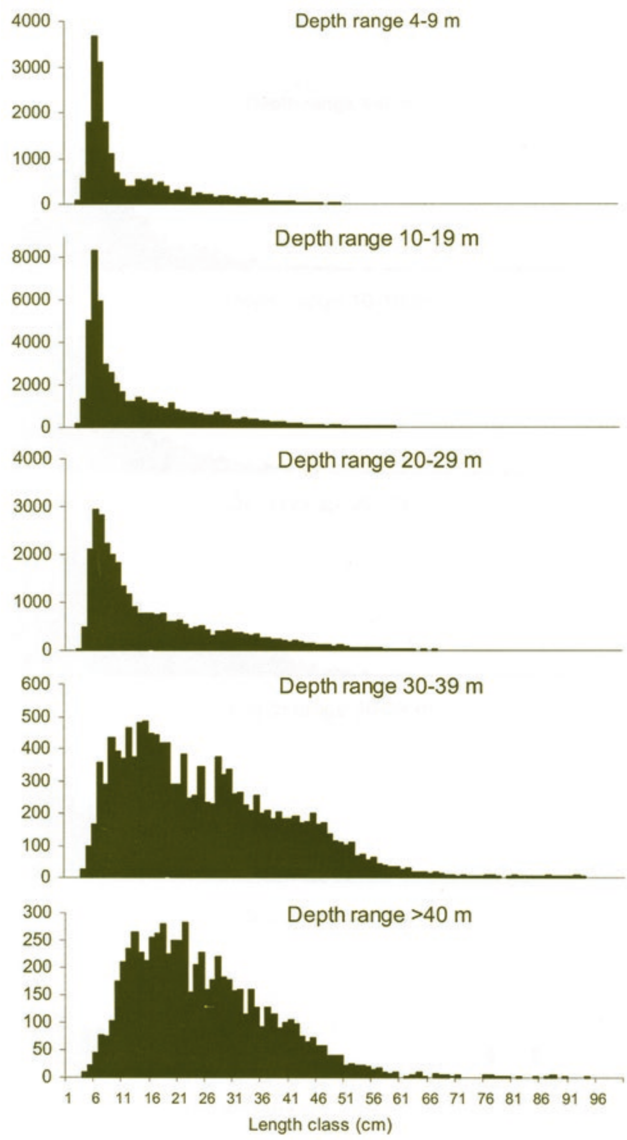

Fig. 6.7 Length frequency distributions for *L. niloticus* from bottom trawling in different depths of Lake Victoria, Tanzania (Source: Cowx 2005)

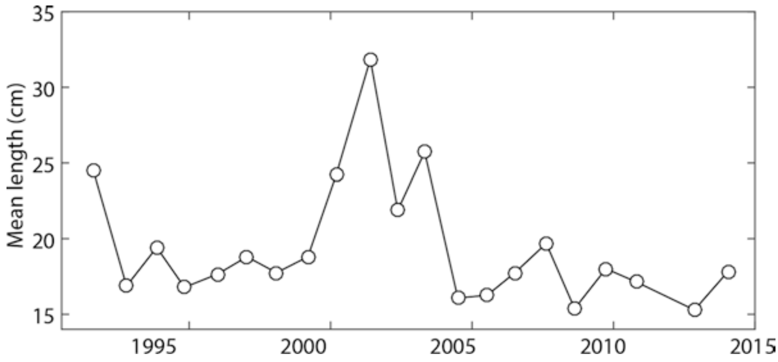

Fig. 6.8 Mean total length (cm) for *L. niloticus* for the period of 1993–2014

trawl net for smaller-sized individuals, and (ii) an excessive exploitation rate in the current fishery. However, the large number of juveniles in the trawl catches indicated that rampant overfishing was probably not a problem (Cowx 2005).

6.3.3 Stock Abundance from Hydroacoustic Survey

Hydroacoustic surveys of Nile perch biomass have been undertaken between 1999 and 2015. The data from 1999 to 2002 were re-analysed to conform to that of 2005 to 2015. These surveys were stratified by lake quadrant (NW, NE, SE and SW), country, 'stratum' (offshore, coastal, and inshore), and special areas (Emin Pasha, Sesse Islands, Nyanza Gulf and Speke Gulf) (Fig. 6.11). The biomass was therefore estimated for each stratum as the product of the Nile perch biomass density and the area of each stratum before summing across the 32 strata. Generally, the total biomass from the surveys remained relatively stable over time. However, the 2015 acoustic survey recorded an increase in the total biomass in the lake from 2.9 million tons in 2014 to almost 3.2 million tons. Furthermore, major changes in fish species composition in the lake were noted with an increase of small pelagics, specifically dagaa and haplochromines and a decrease of Nile perch (Fig. 6.12).

However, during the stratification period where more surveys were conducted, the biomass of Nile perch declined from 1.6 million tonnes in year 2000 to 1.2 million tonnes in 2015 (Fig. 6.12). Nile perch, which composed of 60.3% in 2000 and reached the highest composition of 64.7% in 2001 dropped to 35.6% by 2015. Generally, the population structure of Nile perch in 2015 from both acoustic single target detections and measurement of specimens retained by net hauls indicated the population was skewed in favour of juveniles. From single target detections, the mean length of Nile perch detected was 29.4 cm TL, while 5.5% by number were above the lower limit of the slot size. For Nile perch caught by net during the acoustic survey, the overall mean length was at 12.3 cm TL with 0.4% of Nile perch above the lower limit of the slot size.

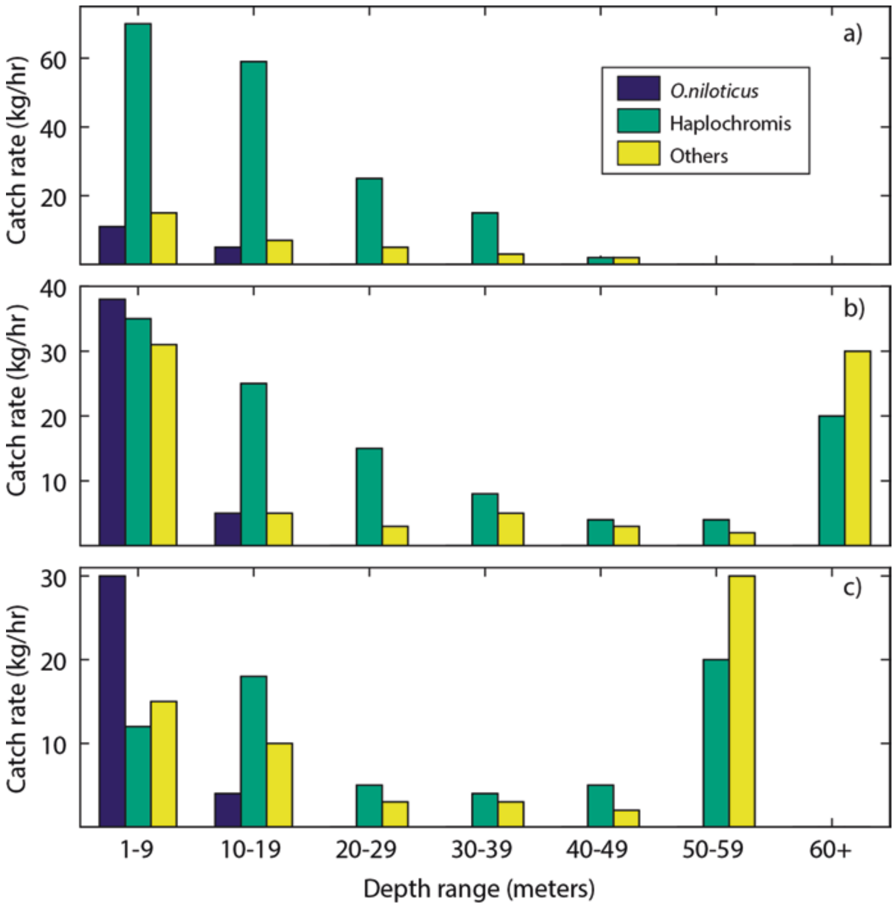

Fig. 6.9 Variations in catch rates of *O. niloticus*, haplochromines and the other species in bottom trawls by depths and zones in the Tanzanian sector of Lake Victoria. Error bars represent ±SD (Redrawn from Cowx 2005)

Generally, the biomass of dagaa showed stability and consistent increase over the years (Fig. 6.13). Dagaa biomass in 2000 was 0.90 million t, but by 2015 it had increased to 1.4 million t. Dagaa biomass constituted 20.2% in 2000, reaching a maximum of 44.4% in 2014, but decreased to 40.7% in 2015. Dagaa is an annual species, which completes its life cycle in just one year. The estimated biomass (1.4 million t) compared to the recorded catches from catch assessment survey (CAS) suggests that the resource is still underexploited and therefore more investment is warranted, with stock assessment model recommending that up to 70% of biomass can be harvested without compromising the ability of the stock to replenish itself (Kayanda et al. 2009). The haplochromines and other species (Others) doubled between 1999 and 2015 (Fig. 6.13). They constituted 19.5% in 2000, reaching a maximum of 27.7% in 2011 and decreased to 23.7% in 2015. While this could be

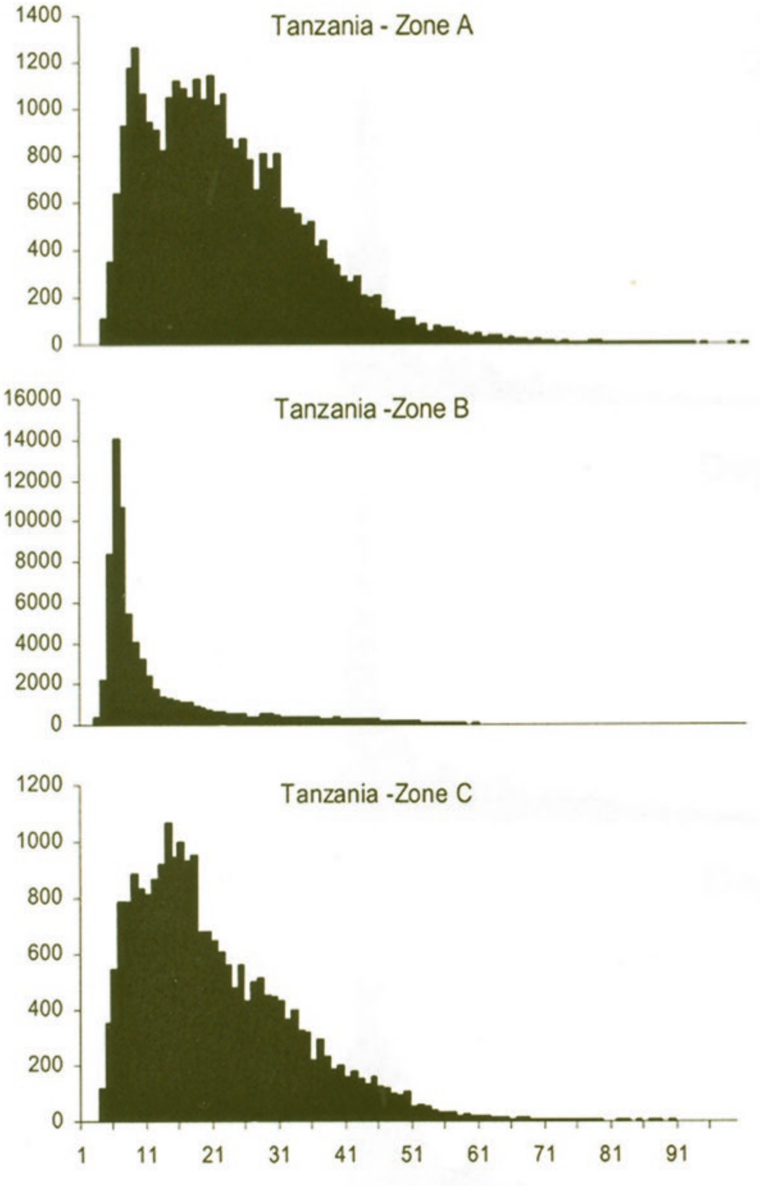

Fig. 6.10 Length frequency distributions (x-axis values in cm) for *L. niloticus* from bottom trawling in different zones of Lake Victoria (Source: Cowx, 2005)

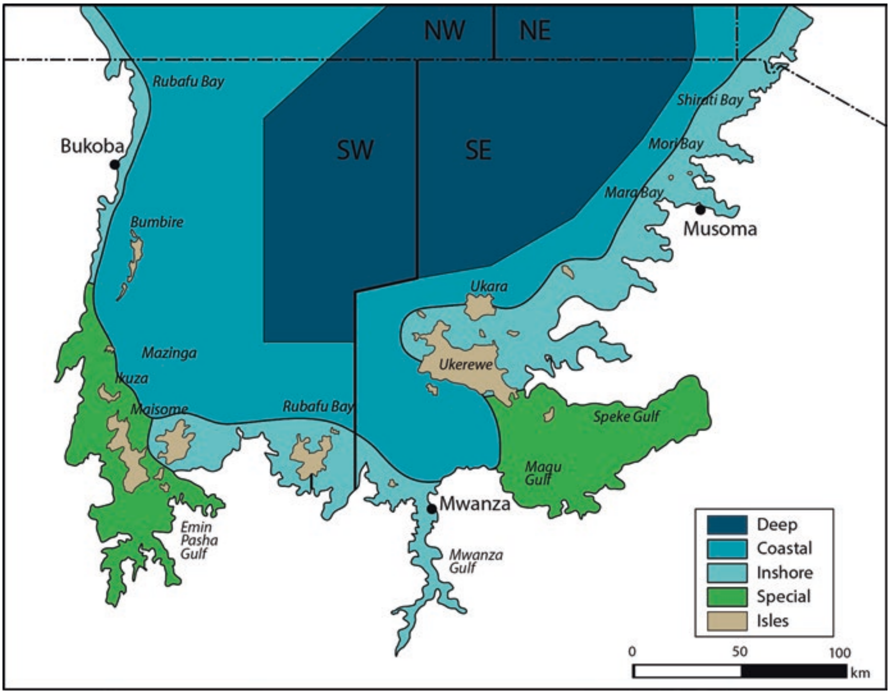

Fig. 6.11 Hydroacoustic surveys' quadrants, strata and special areas

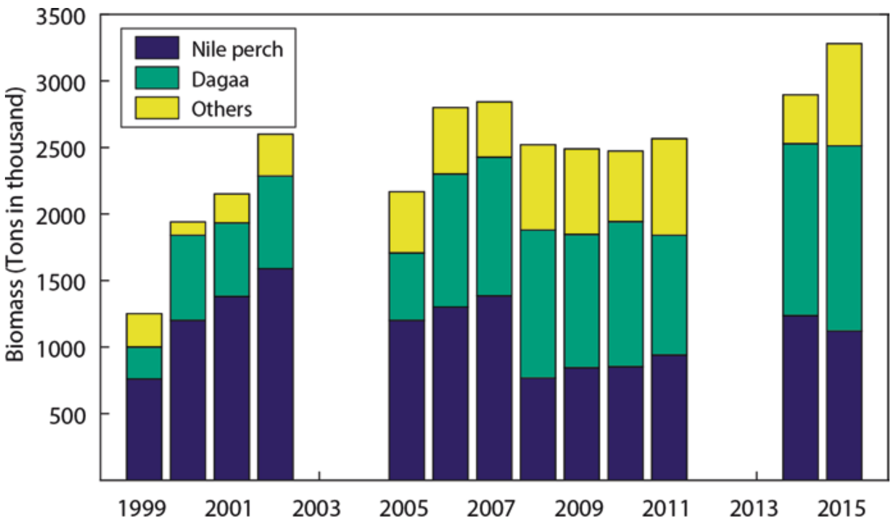

Fig. 6.12 The biomass of Nile perch, dagaa and Other species from 1999 to 2015. The bars for Nile perch biomass represent the average of the two surveys conducted within the same year

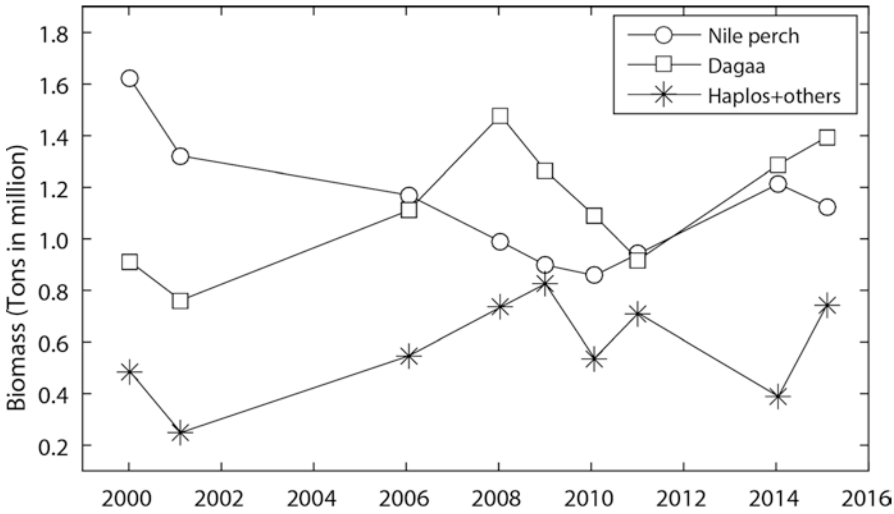

Fig. 6.13 Estimates of Nile perch, dagaa and haplochromines + Others biomass from the lake-wide hydroacoustic survey (1999–2015). Only estimates for the stratified lake season are shown

mainly a result of predator-prey relationship and favourable environmental conditions, a close observation of the stock is important especially now when there is a major recovery of haplochromines.

When looking at only the stratification season where most of the acoustic surveys were conducted, the biomass in the Tanzanian part of the lake in which the SW and SE quadrants fall, the trend is the same as that of the whole lake. The biomass of Nile perch declined from 0.8 million t in 2000 to 0.4 million t in 2011, and increased to 0.6 million t in 2015 (Fig. 6.14). During the same period, dagaa biomass doubled from 0.4 million t in 2000 to 0.8 million t in 2015, and haplochromines and 'others' also almost doubled during the same period, i.e. from 0.5 million t in 2000 to 0.8 million t in 2015.

6.3.4 Abundance from Gillnet Catches

Catch assessment surveys conducted in 1999 and 2000 showed that motorized boats with gillnets had the highest catch per unit effort (CPUE) of 69.26 and 73.19 kg/day respectively compared to the other gear. There was a marked difference in CPUE between motorized gillnet boats and gillnet boats with sails, 69.26 kg/day and 31.10 kg/day, respectively in 1999 and 73.09 kg/day and 39.26 kg/day, respectively in 2000. This lead to further assessment of CPUE for motorized gillnet boats which had information on the number of nets from October 1997 to December 2000 (Table 6.7).

The catch per boat appeared to have increased by 13.8% from October 1997 to December 2000 and the number of nets per boat increased by 100% indicating a

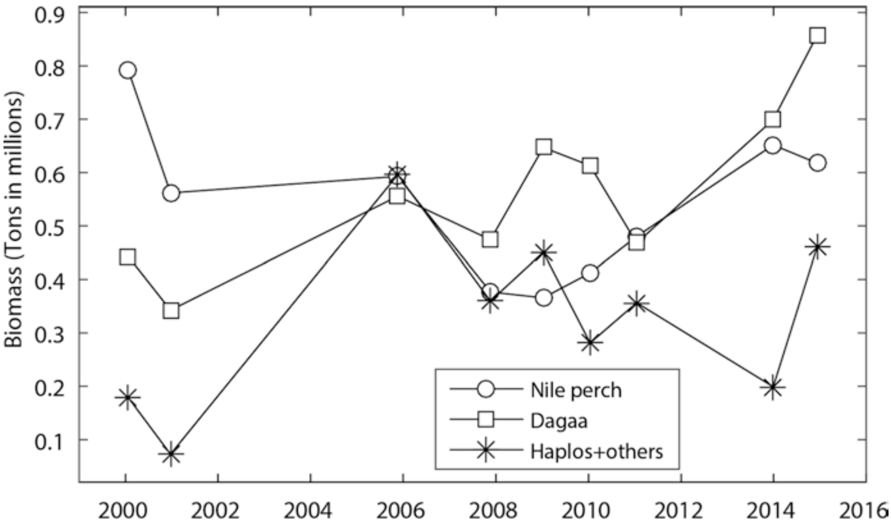

Fig. 6.14 Estimates of Nile perch, dagaa and haplochromines + 'Others' biomass from the hydroacoustic survey (1999–2015), in the Tanzanian part of the lake. Only estimates for the stratified lake season are shown

Table 6.7 Changes in catch rates (kg/net) and number of gillnets per boat for Nile perch fishery from 1997 to 2000 in Tanzanian waters

Year	Catch rates (± 95% CL) (kg boat^{-1})	Number of nets boat^{-1} (± 95 CL)	Catch rate (kg net^{-1})
1997	65.69 ± 21.39 (N = 17)	45.5 ± 8.53	1.45
1998	58.35 ± 13.24 (N = 49)	51.3 ± 6.54	1.14
1999	77 0.0 ± 30.74 (N = 21)	99.14 ± 12.9	0.78
2000	74.79 ± 12.75 (N = 37)	90.16 ± 9.1	0.83

Source: TAFIRI survey data

marked decline in CPUE. Catch per net declined by almost 60%. The fishermen vary the fishing techniques from active gillnetting to triple-mounting of nets (two to three nets are joined vertically so as to cover the whole water column). Such mounted nets are also tied to canoes with outboard engines and towed slowly over a large distance, thus increasing the fished area. All these actions constitute attempts to increase CPUE, but have negative impacts on the fishery in the long run.

6.4 Discussion

6.4.1 Trawl Catches

Stock abundance fluctuated over the years, but due to changes in species composition and the data collected by different research vessels of varying efficiency under different sampling programmes, it was not possible to establish trends. However, when haplochromines dominated in the early 1970s, catch rates were more than 400 kg/h (Table 6.2), but fell dramatically thereafter. As haplochromines declined, the Nile perch increased in the early 1980s. Despite differences in the vessels used, Nile perch catch rates followed an increasing trend throughout the 1980s and 1990s (Fig. 6.1). The increase in the abundance of the Nile perch was parallel to a decrease in the abundance of the important prey item—the haplochromines.

Seasonality in environmental factors greatly influenced the distribution and abundance of the Nile perch stocks. Temporal distribution of the Nile perch stock appeared to have a cyclic pattern in relative abundances, following the period of complete mixing of the water column, i.e. June to August. Mixing causes a relatively even distribution of dissolved oxygen as well as food items in the water column, and in turn the distribution of the Nile perch and its availability in the bottom trawl catches; while the period of January–March, with the lowest abundances, is the period of thermal stratification.

The batho-spatial distribution pattern exhibited a decrease in stock abundance with depth. High catch rates were recorded at the depth range of 30–39 m, which was different from the 1995 observations (Witte et al. 1995) when the highest catch rates were at 15–25 m depth. Changes in prey species and their distribution and abundances together with the variations in environmental parameters were probably the influencing factors.

The Nile perch seem to form aggregations, as very high densities of up to 33 t/km^2 were found in one area while the adjacent area could be with less than 2 t/km^2. Such behaviour contributes to the threat of severe stock collapse, as the fish are more vulnerable to capture if the distribution patterns are known. The trawl surveys conducted during the Lake Victoria Environmental Management Project (LVEMP) (2000–2002) showed that different fish species were distributed differently in different areas. This could be attributed to a combination of factors, including food items and environmental factors. For example, there was a high abundance of the Nile perch in the Speke Gulf, which was coupled with a good recovery of the haplochromines (an important prey).

Although the current biomass estimates seem to be comparable to previous estimates and predictions (Bundy and Pitcher 1995; Moreau 1995), and the effect of the excessive effort to stock biomass is not evident, the present size composition of the stocks and of the catch, and the aggregating behaviour of the Nile perch as an important commercial fish species, call for management interventions for the sustainability of the fishery.

Seasonal changes have been proven to affect the catch rates of Nile perch in Lake Victoria. Based on the two dry and wet seasons, the variations were significantly different ($p = 0.0002$ at $\alpha = 0.05$) whereby the dry season has been shown to have a higher catch rate (Mkumbo 2002; Mlaponi et al. 2009; Mlaponi 2011). The surveys were conducted during the period of stable thermal stratification (January to March/April), when oxygen is limited to low depths thus leading to anoxic conditions in deep waters. Anoxicity causes the Nile perch to move into shallow waters because they are sensitive to low oxygen (Talling 1966; Mugidde et al. 2005; Mlaponi 2011). Nile perch cannot tolerate dissolved oxygen concentrations lower than 2.5 mg/L (Hecky et al. 1994; Wanink et al. 2001; Taabu-Munyaho et al. 2013). The situation may contribute to low catch as bottom trawlers operate at the bottom (Mlaponi et al. 2008; Mlaponi 2011).

Moreover, there is a decrease in mean catch rate when compared to the surveys conducted between 2003 to 2008 under the IFMP project (Fig. 6.1b). This decrease in catch rate for Nile perch and Nile tilapia could be attributed to high fishing mortality as a result of increasing fishing effort and environmental change. Haplochromine species which are the major food source for Nile perch show an increase in catch rate over time although at a smaller rate of $r = 0.12$. Frame Survey results show an increase of fishing effort in terms of fishers, boats and fishing gear over time. The decline of catch has caused fishers to improve the efficiency of fishing gear by joining gill nets vertically up to more than six panels deep and this in turn has increased fishing pressure in the lake (Mkumbo and Mlaponi 2007).

Furthermore, since the Nile perch catch has been dominated by fish of sizes lower than the slot size, the proportion by weight of large sized fish (above 50 cm TL) has been decreasing since 1998 (LVFO 2011).

Overall, the trend of the mean catch of haplochromines (Fig. 6.1b) shows an increasing pattern compared with Nile perch and other species grouped together. This may be a result of low competition from other species occupying the same niche and having different ecological habitats.

6.4.2 Hydroacoustic Surveys

Despite having an increase in biomass of Nile perch in the 2015 survey, generally, there is a significant and monotonic decline (Fig. 6.13), with the overall rate of decline estimated from the linear regression being 65,792 t per year, equivalent to 0.98 t/km^2 per year (~ 1 $t/km^2/yr^1$). Biomass estimates also varied significantly ($p < 0.05$) within each of these strata (Fig. 6.11). The rate and the extent of spatially and localised depletion, particularly in the lake gulfs, is clearly evident. However, all 32 strata show a declining trend. In the Emin Pasha and Speke Gulfs, Nile perch mean biomass decreased from 24.2 to 2.4 tonnes and 19.4 to 9.5 tonnes between 1999–2007 and 2008–2011, respectively, clearly indicating localised depletion especially in the Emin Pasha Gulf. Furthermore, the proportion of Nile perch above the lower limit of the slot size has progressively reduced over the years from August 2006 to

November 2015 survey. This decrease in the numbers of fish above the slot size has created difficulties for the export industry which led some of them to close completely and those which are in operation are operating below their installed capacity. In addition, the current emerging business of fish maws, which mainly target larger individuals above the upper limit of slot size is increasing the exploitation of large fish which could impair the ability of the stock to replenish itself.

This decreasing trend of Nile perch biomass is mainly attributed to increased fishing effort and power over time. The 2012 and 2014 Frame survey data indicated a notable increase in all major effort groups, which include the number of fishers, fishing crafts, gillnets, long line hooks and outboard engines. From 2010 to 2014, the numbers of fishers increased by 1.5%, while the number of fishing crafts increased by 1.4%. The number of crafts with outboard motors also increased by almost 7.9% across the same period, targeting mainly Nile perch (64.8% of all outboard engines) and dagaa (33.6% of all outboard engines). The high proportions in numbers of outboard engines reflect the rapid growth in effort directed at these species (LVFO 2015). In addition, the total number of gill nets increased by 19% between 2010 and 2012, while a further increase of 58.2% was recorded between 2012 and 2014. Hooks which were almost non-existent in 2000, increased significantly over the years with a notable increase in small hook sizes. The Frame Survey conducted in 2014 showed that over 98% (12,317,010 hooks) of all long line hooks targeted Nile perch. Out of these 76.9% fall under the small size category. This indicates a major shift from the usage of big to small hooks mainly to target smaller Nile perch below the lower limit of slot size, which comprise higher proportion of biomass and hence increase the problem of growth overfishing.

The biomass of *R. argentea* (dagaa) showed an increasing trend over time in all strata especially the survey carried out in 2015. However, this increase is only noted in Kenya and Tanzania where all strata recorded an increase except for Nyanza Gulf in Kenya and Southwest Deep and Coastal strata in Tanzania. Uganda recorded a decrease in dagaa in all strata except Northeast Inshore stratum. Generally, for the 2015 survey, the highest concentration of dagaa was found in the deep strata of the southern half of the lake. In addition, coastal stratum of the Southeast quadrant also recorded higher biomass of dagaa. The increase in the biomass of dagaa started in the 1980s following the establishment of the introduced Nile perch and the decrease in haplochromines (Wanink 1991) and is still increasing. Several factors have been suggested for the increase in the biomass of dagaa in the lake. The niche shift to the bottom layers after the decline and near disappearance of the haplochromines (Wanink 1998) has enabled dagaa to exploit the chironomid larvae and *Caridina nilotica* (Wanink 1998), which increased strongly in the 1980s (Witte et al. 1995). The disappearance of most of the haplochromines may have reduced competition for food with dagaa (Witte et al. 1992). In addition, reduction in generation time and increased growth rate are thought to have contributed to the increase in the biomass of dagaa (Wanink 1996).

Possible reasons for further increase in the biomass of dagaa include the decrease in the biomass of the predator, Nile perch, as indicated by a decrease in commercial catches in the Kenyan (Njiru et al. 2002) and Tanzanian (Mkumbo et al. 2002) parts of Lake Victoria. This may have resulted in reduced predation pressure and provided a spare niche for colonisation. Furthermore, the decrease in the infestation of dagaa by *Ligula intestinalis* could have caused further increase in this species' biomass. *L. intestinalis* has been found to affect maturation, hence reducing the fecundity of dagaa (Tumwebaze 2003).

When comparing the periods between 1999 and 2007 and from 2008 to 2011, the biomass of haplochromines and other species slightly increased in all strata, except for the Emin Pasha Gulf, which declined from 32.6 to 16.0 tonnes within the same period. The exception is in the most recent survey of 2014, which shows a general decrease. Furthermore, the haplochromines and other species almost doubled between September 2014 and November 2015 (Fig. 6.12). The stock dynamics observed could mainly be a result of predator-prey interactions and favourable environmental conditions.

In the 1980s, the pelagic community's biomass changed considerably, in Lake Victoria, following a decline in the haplochromines and an increase in *R. argentea* (Ogutu-Ohwayo 1990; Witte et al. 1992). The decline in haplochromines is thought to have been mainly due to predation by the Nile perch (Witte et al. 1992), although overfishing and changes in the environment could have contributed to the situation (Harrison et al. 1989; Seehausen et al. 1997). During the second half of the 1990s, a recovery of haplochromines was observed in the southern part of the lake (Witte et al. 2000) and in the northern part (Namulemo 1999).

The species showing recovery are mainly the zooplanktivores—*Haplochromis (Yssichromis) pyrrhocephalus* and *H. (Y.) laparogramma* (Witte et al. 2000). Trawl catches of haplochromines during the five acoustic surveys had a bigger percentage of *H. (Y.) laparogramma*. A further increase in haplochromines may have been caused by a decline in the Nile perch catches as indicated by a decrease in commercial catches in the Kenyan (Njiru et al. 2002) and Tanzanian (Mkumbo et al. 2002) parts of the lake. A close observation of the stock is important in quantifying which species among the recovered ones are actually decreasing or increasing.

The freshwater shrimp, *C. nilotica*, is widely distributed and highly abundant in almost all habitats in Lake Victoria. *C. nilotica* is abundant in deep open offshore waters and is extremely abundant in the inshore bays, in littoral and sub-littoral regions in the beds of submerged vegetation (Budeba 2003). The occurrence of *C. nilotica* in different habitats is an indication of successful establishment of the shrimp in Lake Victoria (Budeba 2003). Members of the genus *Caridina* and the Atyidae in general, are successful in tropical systems where all-year-round rates of biological metabolism and oxygen demand at sediment surfaces are high in comparison with temperate lakes (Beadle 1981). Despite the high abundance of *C. nilotica* in Lake Victoria, their distribution and abundance showed spatial and temporal variability.

6.4.3 Gillnet Catches

Historical data shows an increase in effort and the shift from small mesh-size to larger mesh-size nets as the Nile perch fishery developed. Currently, however, there is a shift towards smaller mesh sizes, as a result of the excessive effort and the decrease in catch per unit of effort (CPUE), plus fishermen innovating different catch techniques such as drifting or towing of gillnets, and the vertical joining of gillnets to cover the whole water column.

The decreasing trend in CPUE found for Tanzania was prevalent in the other two countries. The double or triple mounting of gillnets to increase the catch rates reported in Tanzania was also observed in Kenya and Uganda (Mkumbo 2002), while any increase in CPUE is fundamentally harvesting juveniles which constitute 80% of the Nile perch catches. The slight increase in CPUE for gillnet motorised boats and gillnet paddled boats recorded in the Tanzanian waters could be explained by the changes in fishing practises. Motorised vessels explore distant fishing grounds whilst using triple stretched gillnets to cover more of the water column. The gillnet paddled boats are the ones operating in inshore areas and these tend to use meshes below 5″ so as to catch the tilapiines and other inshore species like *Brycinus* spp. and *Schilbe* spp.; however, they coincidentally catch Nile perch juveniles.

The yield estimated for 1999 was almost 20% less than the 2000 yield, probably due to the export ban of the Nile perch to the EU markets resulting in few boats fishing because of low prices. The ban was lifted at the end of 1999, which increased the demand and an increase in the proportion of boats fishing in 2000. The gillnet fleet which was once dominated by 7–9 in. mesh size (Ligtvoet and Mkumbo 1991) has become dominated by a mesh size of 5–6 in.

6.5 Conclusion

The current biomass estimates from trawl surveys indicated a slightly declining trend over time, which was also observed in the hydroacoustic surveys results. There were considerable spatial and temporal changes in the distribution and abundance of the Nile perch and other species from the trawl survey data, which were corroborated by the hydroacoustic surveys. This variability is important for the management of the fishery in the sense that the Nile perch occupies preferred habitats, notably shallow inshore waters and areas around islands, despite its ability to move across great distances.

The available data indicate that the abundance of Nile perch declined over the two-year surveys conducted between 1999 and 2001, most likely due to high fishing pressure. However, the resurging biomass of small pelagics (dagaa and haplochromines), as a result of heavy exploitation of their predator, the Nile perch, appears to have compensated for the decline in the standing stock of the latter.

6.6 Recommendations

The following recommendations are focused on unfinished business with the LVEMP I that should be taken up by LVEMP II and other follow on programmes:

- The recommendation for the establishment of aquatic parks in nursery grounds (bays), which were identified during the LVEMP I should be implemented. This would protect the juveniles, which are usually caught using illegal fishing gears (small meshed nets).
- Little is known about habitat utilisation by the Nile perch in Lake Victoria. There is a need to investigate and establish the type of habitats that are preferred by the Nile perch for feeding and breeding grounds. The information generated through such investigations will be directly relevant to establishing closed areas and seasons for fishing.
- Studies on the relationship between environmental parameters and fisheries should be strengthened. This would assist in deciding when and where to close the fishery.
- Gillnet fishery needs to be investigated, as passive gillnets or towed or single triple mounted gillnets have different influences on the catch per unit of effort. Even the number of gillnet units has some effect on stocks.
- Studies on the effect of processing plants on the stocks of the Nile perch need to be conducted.

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Chapter 7
Aquaculture and Fisheries Extension

A.P. Shoko, Yunus D. Mgaya, S.M. Limbu, and R.B. Hoza

Abstract The dwindling catch from Lake Victoria has caused an insufficient fish supply to the population of the Lake Victoria basin, Tanzania. The decrease in catch rates and demand for fish has created room for fish farming practices at both small and commercial scales in the Lake Basin. This chapter provides a result-oriented status of aquaculture research and development efforts made by the government and Non-Governmental Organizations (NGOs) in the Lake Basin from the colonial era to the present. The chapter also highlights strengths, weaknesses, opportunities and challenges (SWOCs) to aquaculture development in the basin. Results show that the basin has a high potential for fish farming development due to suitable characteristics for fish farming. Fishponds are the common culture system used in fish farming in the basin. The ponds are stocked with either Nile tilapia *Oreochromis niloticus* or African sharptooth catfish, *Clarias gariepinus*, reared in monoculture or polyculture. A system of integrated aquaculture-agriculture (IAA) farming is also practised in some areas of the basin. The yield from the lake basin has increased with time due to improved pond management techniques. However, more room is available for further increase pending the adoption of technology and improved extension services. Fish farming could help to reduce fishing pressure on capture fisheries in the main lake and contribute significantly to the conservation of the lake's biodiversity. Ultimately, fish farming will generate income for the people, which is in line with the government's efforts to alleviate poverty in the country.

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7.1 Introduction

The falling fish catches from Lake Victoria has led to inadequate fish supply for the population within the Lake Victoria Basin, and Tanzania in general. The export trade of fish, especially of Nile perch (*Lates niloticus*), and a decline in its catches contribute to the inadequate supply of fish protein to the riparian communities and other people living outside the basin. Fish production from the main lake has decreased due to the effects of multiple stressors including the increased use of destructive fishing methods, high fishing pressure, the introduction of the Nile perch (*L. niloticus*), environmental destruction, and the disappearance of indigenous fish species (Matsuishi et al. 2006; Hecky et al. 2010). Similarly, the increasing population pressure, industrial development and other socio-economic activities in the lake basin have resulted in changes in water quality, fisheries biodiversity, wetlands and land use (Kitula 2006; see also Chapter 3 of this volume). These changes have consequently resulted into a general decrease of fish stocks and fisheries biodiversity (Balirwa et al. 2003) leading to a limited source of protein. Given the increasing demand for, and the limited supply of fish from natural capture fisheries, there is an urgent need to look for alternative means of producing fish as a cheap source of protein for the inhabitants of the basin and beyond.

The decline in catch rates and high demand for fish have created significant opportunities for fish farming practices at both small and commercial scales (Balirwa 2007). Fish farming has the potential to increase fish supply and bring socio-economic benefits to the riparian communities because the basin meets the criteria for fish farming. Fish farming is considered important in increasing fish production in rural areas and can be productively integrated with crop and animal husbandry. Thus, fish farming practice in the Lake Victoria Basin could increase fish supply to the riparian communities and improve the livelihoods of the poor through increased food supply, employment and income.

Despite the fact that fish farming in the Lake Victoria Basin was introduced during the colonial era (Fisheries Division 1967; Bwathondi and Mahika 1997), the activity has not developed significantly. Since independence, the government of Tanzania has made some efforts to increase fish farming in the basin. Unfortunately, those efforts have not yet resulted in any significant development; fish farming practices have remained at the level of subsistence. Specifically, emphasis on fish farming research and development in the Lake Victoria Basin started in the early 1960s when fish ponds were established at the Malya fish farm in Kwimba District, Mwanza Region (Fisheries Division 1967). However, such emphasis did not lead to substantive production of fish.

Following previous efforts, other initiatives on fish farming started during 1990s when baseline surveys (Bwathondi and Mahika 1997) were conducted to explore its potential. The inception of the Lake Victoria Environment Management Project (LVEMP) in 1997 made deliberate efforts to promote fish farming in the basin. Such efforts included training of fisheries extension staff on fish farming development, training of farmers on pond construction and management, construction of demonstration fishponds, and the establishment of breeding ponds as a source of fish fingerlings. These activities were carried out at the Tanzania Fisheries Research Institute (TAFIRI) – Mwanza Centre, Nyegezi Freshwater Fisheries Training Institute (NFFTI) in Mwanza and Magoma village in Tarime District, Mara Region.

Apart from attempts led by the government, there have been some efforts by Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs) in promoting fish farming activities. Such efforts, though uncoordinated, have made a positive impact towards aquaculture development in the basin. By recognizing the efforts made by NGOs and CBOs, the LVEMP established a collaborative mechanism with these organizations in order to promote fish farming practices in the basin. Lake Victoria Research Initiative (VicRes), a Sida/SAREC funded project has also made an important contribution in aquaculture research and development by supporting different researches aimed at improving fish yields and income generation for local communities (Getabu et al. 2007; Shoko et al. 2011a).

Effective extension service is one of the main aspects required for aquaculture development (Brummett and Williams 2000). Fisheries extension services in the Lake basin started during the colonial era. They have been responsible for the dissemination of information on available fish stocks, sustainable fish harvesting practices, improved fish handling and processing methods and proper care and maintenance of fishing gear. Other activities include fishing demonstrations, promotion of fish consumption as food, and serving as a bridge between resource users, managers and researchers. However, fisheries extension services have been ineffective because of inadequate number of trained staffs, budgetary constraints, and poorly coordinated institutional framework. Despite the setbacks, fisheries extension services such as those provided by the government and the LVEMP have largely supported the current knowledge on fish farming activities in the basin. These efforts have collectively resulted into vibrant aquaculture activities in the basin.

The rise and fall in fish farming activities over time have characterized developments in fish culture practices in the Lake Victoria Basin, Tanzania. Reports show that donor supported post-colonial aquaculture initiatives failed because they were top-down arrangements made between the government and donors, which typically alienated the farmer (Bwathondi and Mahika 1997; Bwathondi et al. 1998). The approach by the LVEMP, of enabling farmers to own the activity, deviates significantly from the experience of the past. Under this setup, farmers are provided with technical support such as pond siting, construction, management and simple fish feed formulation techniques by using locally available ingredients. Besides, community-based breeding ponds have been established in collaboration with farmers, which make the supply of fish fingerlings easier. People, including interested farmers, are also encouraged to establish private facilities for producing fish farming inputs such as fish feeds and commercial hatcheries offering fish fingerlings for sale. Such approaches ensure the sustainability and success of fish farming beyond the project phase.

Despite appreciable efforts made by the government and the private sector in fish farming development in Lake Victoria Basin, the available information is scattered and unfocused. In view of the foregoing narrative, the objective of this chapter is to review the aquaculture research and development efforts made by the government, CBOs and NGOs in the Tanzanian part of the lake basin from the colonial era to the present, including the development attained during the LVEMP I. The chapter also highlights strengths, weaknesses, opportunities and challenges (SWOCs) to aquaculture development in the basin. Recommendations for future research and development of aquaculture are also given.

7.2 Results

7.2.1 Fish Farming Potential

Results from the baseline studies conducted in the Tanzanian part of the Lake Victoria Basin, showed that there is a high potential for fish farming development, which is yet to be fully utilized (Bwathondi et al. 1993, 1998; Bwathondi and Mahika 1997; Mahika et al. 2001; Mbilinyi and Shoko 2002; Shoko et al. 2011b; Salehe et al. 2012; Rothuis et al. 2014). This potential is indicated by favourable conditions for fish farming activities such as suitable soils, and permanent sources of water from rivers and numerous springs throughout the year in certain areas. Other indicators for fish farming potential include suitable temperatures and abundant animal manure, which is an important input for fishpond fertilization in extensive and semi intensive production. There is a reliable market for fish ranging from local markets where most households buy their fish, to hotels and restaurants where fish can be incorporated in menus, and fish butcheries where fish are prepared and sold while fresh or frozen (Salehe et al. 2012; Rothuis et al. 2014). It was further established that fish farming is mostly favoured in the districts of Tarime (Mara Region), Muleba, Bukoba Rural and Urban (Kagera Region).

A study conducted by Shoko and Onyango (2005) reported that Ngara District in Kagera Region is another important potential area for fish farming. The basin also has diverse wetlands, which if wisely utilized, could be used for fish farming development without affecting their primary role. In addition, a large majority of people in the basin prefer fish farming practice as an important economic activity, which is another opportunity that should be tapped to promote fish farming in the Lake Victoria Basin.

7.2.2 Culture Systems Used

In the Lake Victoria Basin, the most important fish farming system is pond culture of Nile tilapia (*Oreochoromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*) (Shoko et al. 2003a, 2011a; c, 2014, 2016a, b; Imani et al. 2014; Musiba et al. 2014). Cage culture of tilapia has also, been experimented, since the late 1960s

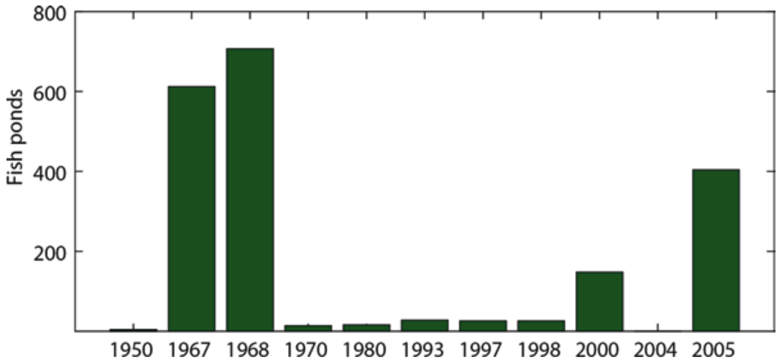

Fig. 7.1 Total number and average yield of fish ponds in the Lake Victoria Basin, Tanzania (Source: Fisheries Division 1967, 1968, 2005; Bwathondi et al. 1993, 1998; Bwathondi and Mahika 1997; Mahika et al. 2001)

to the present, at the NFFTI and TAFIRI Mwanza Centre (NFFTI 1972; Kashindye et al. 2015). Cage culture provides an opportunity for increasing fish supply from aquaculture given the abundance of water from Lake Victoria and many smaller lakes in the basin. Few farmers are practising integrated aquaculture-agriculture systems composed of fish, vegetables and animals. The vegetables used in integration include Kale *Brassica oleracea* (Shoko et al. 2011a) and animals such as chickens.

7.2.3 Number, Size and Yield of Fishponds

Existing records show that fish farming in the Lake Victoria Basin started back in 1950s during the colonial era. The Malya fish farm in Kwimba District, Mwanza Region, was established for promoting fish farming and restocking Lake Victoria (Fig. 7.1) (Fisheries Division 1967, 1968; Bwathondi and Mahika 1997). Furthermore, fish farming was introduced in Kagera and Mara Regions in the 1960s by the Fisheries Department (Fig. 7.1). Available records show that during this period, fish farming practices increased as evidenced by 612 and 707 fishponds in 1967 and 1968, respectively (Fig. 7.1). Fish farming practice in the basin was almost stagnant between the 1970s and the early 1990s as indicated by only 14 to 26 fishponds from 1970 to 1998, respectively.

However, things changed for the better from the late 1990s to 2005 as evidenced by a significant ($p < 0.05$) increase in the number of fishponds from 148 in 2000 to 404 in 2005 (Fig. 7.1). An average fishpond yield of 1,823 kg/ha was reported by Shoko et al. (2011c) from the potential areas (Fig. 7.1). The study however, reported no significant difference ($p > 0.05$) in pond yields between the potential areas of the districts of Muleba and Bukoba in Kagera and Tarime in Mara Regions. Because of

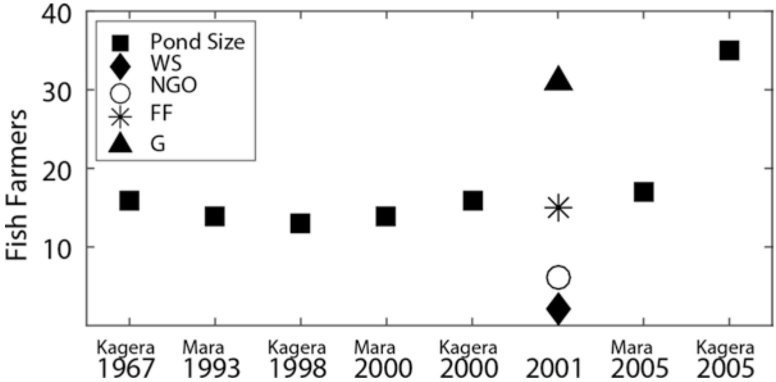

Fig. 7.2 Average size of fishponds and sources of fingerlings in the Lake Victoria Basin, Tanzania. (Source: TAFIRI Unpublished Reports). Key: WS = Wild Sources, FF = Farmer to Farmer, NGO = Non-Governmental Organization, G = Government

the lack of consistent data on fishpond production, the increase in the number of fishponds was not correlated with the yields.

The results indicated a further increase in the average size of fishponds in Mara and Kagera Regions of the Lake Victoria Basin, Tanzania (Fig. 7.2). The sizes of two dams (16,500 m^2 and 30,000 m^2) in Tarime District, which were constructed and stocked in 1967 and 1968 (Fisheries Division 1967) are not included in Fig. 7.2. There is no information on the pond sizes from Mwanza Region. The number of people involved in fish farming activities in the whole basin increased from 60 in 1998 (Bwathondi et al. 1998) to 500 in 2005 (TAFIRI, unpublished data). The available information does not indicate the number of people involved in fish farming before 1998.

7.2.4 Fish Species Farmed

The survey conducted in the basin recorded several fish species that have been cultured in different areas of the basin over the years. Table 7.1 summarizes the types of fish species cultured from 1967 to 2005. Through research, it was established that the Nile tilapia (*O. niloticus*) and the African sharptooth catfish (*C. gariepinus*) are the preferred cultured species, with *O. niloticus* being the most preferred species. Since 1997, emphasis was put on the culture of these two fish species. However, a study by Shoko and Onyango (2005) found that *O. leucostictus* was mistakenly identified as *O. niloticus* and cultured in some fishponds supervised by NGOs and CBOs.

Table 7.1 Type of fish species cultured in Mara, Mwanza and Kagera Regions of Lake Victoria Basin, Tanzania

Year/Region	Mara	Mwanza	Kagera
1967		*Oreochromis esculentus*	
		T. zillii	*Tilapia zillii*
		T. andersoni	*T. melanopleura*
			T. esculentus
			T. machrochir
1993	*O. niloticus*		
	C. gariepinus		
	Oreochromis spp.		
	P. aethiopicus		
	Tilapiines		
1997		*O. niloticus*	
		C. gariepinus	
		Tilapiines	
1998			*Bagrus docmac*
			O. niloticus
			C. gariepinus
			Tilapia spp.
2000	*O. leucostictus*		*O. leucostictus*
	O. niloticus		*O. niloticus*
	Tilapia spp.		*C. alluadi*
	C. gariepinus		*Barbus altianalis*
2005	*O. niloticus*	*O. niloticus*	*O. niloticus*
	C. gariepinus	*C. gariepinus*	*C. gariepinus*
	O. leucostictus	*O. leucostictus*	*O. leucostictus*

7.2.5 Adoption of Technologies

The cage culture technology, which was experimented with at the NFFTI and TAFIRI (NFFTI 1972; Kashindye et al. 2015) is yet to be adopted by fish farmers in the basin. Poor fishpond management has been reported to be responsible for low pond yields over the years (Fisheries Division 1968; Shoko et al. 2011b; Shoko et al. 2014). Pond fertilization techniques of using cribs were recommended and adopted by fish farmers for pond management. Fish farmers adopted the practices of stocking of fish at a low density of two fingerlings per square metre and feeding their fish with diets containing cotton seed cake as the main ingredient twice per day (Shoko et al. 2003a, b; Shoko 2004). However, recent studies show an increase in stocking density of *O. niloticus* and *C. gariepinus* from 2 to 13 fish m^{-2} (Imani et al. 2014; Shoko et al. 2014, 2015, 2016a, b).

However, it was established that, despite the preference for culture of *C. gariepinus*, it is difficult for farmers to obtain the fingerlings of this species (Shoko and

Onyango 2005). This fish species does not reproduce in captivity. Thus, the technology of producing fingerlings of *C. gariepinus* through artificial spawning was introduced and people were adopting it. One farmer had already adopted the technology by 2004 and in 2005, a total of 15 farmers were in the process of acquiring the technology (Shoko and Onyango 2005). A few farmers (two in Kagera Region and five in Mara Region) have adopted an integrated agriculture-aquaculture system (IAA) where aquaculture is incorporated in other farm enterprises such as animal and crop husbandry (Shoko et al. 2011a).

7.2.6 Extension Services

Training of Fish Farmers and Service Providers

The extension officers in collaboration with researchers and NGOs have trained farmers on various aspects of fish farming as indicated in Fig. 7.3. The training covered general fish culture techniques, artificial spawning of *C. gariepinus* and the integration of aquaculture in other farm enterprises such as crop and animal husbandry. The number of people trained in fish farming rose from 82 in 1998 to 355 in 2003, but dropped to 72 in 2005 (Fig. 7.3).

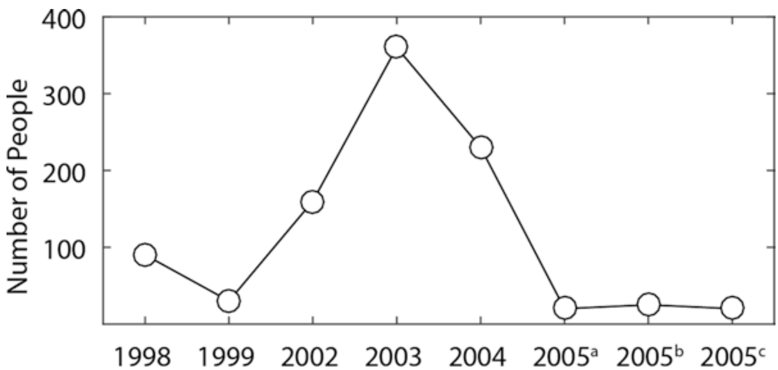

Fig. 7.3 Number of people trained and the type of training offered (See the table below for the type of training offered and source of data)

Year	Type of training	Source
1998	General fish culture techniques	Fisheries Development Division (Shoko AP, personal communication)
1999	Artificial insemination of *C. gariepinus*	Bwathondi et al. (1999)
2002	General fish farming techniques	Mogabiri Agricultural Extension Centre (Shoko AP, personal communication)
2003	General fish farming techniques	Mogabiri Agricultural Extension Centre (Shoko AP, personal communication)
2004	General fish farming techniques	Mogabiri Agricultural Extension Centre (Shoko AP, personal communication)
2005a	Artificial insemination of *C. gariepinus*	Magoma (Shoko AP, personal communication)
2005b	Integrated aquaculture-agriculture (IAA)	Shoko and Onyango (2005)
2005c	General fish farming techniques	Shoko AP. (personal observation)

Non-Governmental Organizations and Community Based Organizations

Findings from several studies have recorded a number of NGOs and CBOs involved in providing fish farming extension services (Bwathondi et al. 1993; Mahika et al. 2001; Shoko and Onyango 2005). These NGOs have been in operation since 1990, which is an average of 15 years. The oldest and youngest organizations are the Tanganyika Christian Refugee Services (TCRS) in Ngara District and the Serengeti District Development Programme (DDP), which have been in operation for 31 years and 1 year, respectively (Shoko and Onyango 2005). Some of the fish farming extension services offered include pond preparation, fertilization and general pond management including harvesting (Shoko and Onyango 2005). A list of these organizations and their areas of operation is summarized in Table 7.2.

Fish Fingerlings Production Centres

During the 1950s and 1960s when fish farming was introduced in the basin, fish fingerlings were obtained from the Malya fish farm and Rwamishenye breeding ponds in Mwanza and Kagera Regions, respectively. Fish fingerlings from Malya fish farm were supplied to areas as far as Kahama and Tabora. Also, Nyalutiti dam which was owned by Rulenge Refugee Camp in Ngara District, Kagera Region was used to supply fingerlings to fish ponds in the Rulenge Camp (Fisheries Division 1968). The Malya fish farm station collapsed after the grant from Food and Agriculture Organization/International Development Agency (FAO/IDA) was stopped; whereas the Rwamishenye breeding ponds collapsed after the government ran short of funds. Thereafter, fish fingerlings were sourced haphazardly.

Table 7.2 NGOs and CBOs offering fish farming extension services

Name of Organization	Organization type	District	Region
Norwegian Peoples AID	NGO	Biharamulo	Kagera
Faiders Group	NGO	Biharamulo	Kagera
Tweyambe Fishing Enterprise	CBO	Muleba	Kagera
Daily Action Development Trust	NGO	Bukoba	Kagera
Tanganyika Christian Refugee Service (TCRS)	NGO	Ngara	Kagera
Relief Development Society (REDESO)	NGO	Ngara	Kagera
Ecovic	NGO	Nyamagana	Mwanza
Heifer Project International (HPI)	NGO	Nyamagana	Mwanza
Community Based Health Program Promotion (CBHPP)	NGO	Serengeti	Mara
Serengeti District Development Program (DDP)	NGO	Serengeti	Mara
Serengeti Farmers Association (SETA)	NGO	Serengeti	Mara
Mogabiri Farmers Extension Centre	NGO	Tarime	Mara
Buhemba Farmers Extension Centre	NGO	Musoma Rural	Mara

Source: Shoko and Onyango (2005)

Efforts to produce fingerlings have been made by some churches such as Mennonite and Lutheran. By the year 2000, quality fish seed production was still a serious problem. Further efforts were made by the NFFTI, Mwanza and the Mennonite Church in collaboration with the Lutheran Church in Arusha to supply fish fingerlings to farmers. According to Mahika et al. (2001) most respondents (62%) obtained fingerlings from NFFTI (Fig. 7.4). Other sources of fish fingerlings included farmer-to-farmer delivery and wild sources (Fig. 7.4). In 2000, the types of fingerlings stocked in ponds showed that the targeted fish species were *O. niloticus* and *C. gariepinus* at 23% and 11%, respectively. Although the above institutions supplied fish fingerlings to farmers, the fingerlings were of poor quality.

In 1997, the LVEMP Project took deliberate measures to produce quality fish fingerlings of *O. niloticus* by establishing four and ten fish breeding ponds at NFFTI and TAFIRI, Mwanza respectively. Breeding ponds established at Nyegezi (NFFTI) and TAFIRI were used as sources of fingerlings for fish farmers. A total of four (4) breeding ponds were also established in Magoma village in Tarime District with the aim of bringing fish fingerlings production centres closer to the community. In addition, fingerlings produced from farmers' ponds have been used by other farmers due to an inadequate supply of fingerlings from NFFTI and TAFIRI.

A fairly modern hatchery was built at TAFIRI Centre, Mwanza in addition to the fish breeding ponds existing at the Centre. The hatchery has two circular concrete and 18 polyethylene ('Polytex') experimental tanks. The facilities in the hatchery were used for conducting fish farming research on the nutrition and

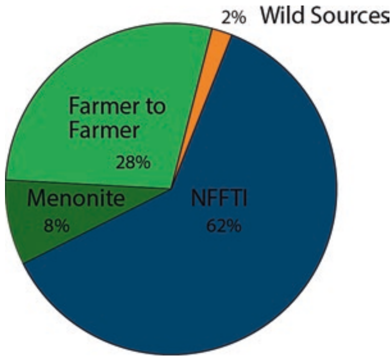

Fig. 7.4 Sources of fish fingerlings in the Lake Victoria Basin in the year 2000

artificial spawning of *C. gariepinus* and for training of farmers. All these activities were aimed at developing appropriate fish farming technologies in order to enhance fish production and alleviate poverty in the three riparian regions.

Following the LVEMP intervention, the Fisheries Management component in collaboration with TAFIRI, supplied a total of 21,743 *O. niloticus* fingerlings to fish farmers in the Lake Victoria Basin from 1999 to 2005. The Kagera Region received the highest number of fingerlings (11,670) followed by Mara Region (6,068) and Mwanza Region (3,930). Apart from the Lake Victoria Basin, some fingerlings were supplied to Morogoro Region (700) and Tabora Region (1,740). Additionally, a total of 2,800 *C. gariepinus* fingerlings were produced by TAFIRI Mwanza researchers in collaboration with the Heifer Project International (HPI), an international NGO based in the Lake Victoria Zone. The fingerlings were supplied to fish farmers in Misungwi District, Mwanza. However, there are no records on the number of fingerlings distributed in the basin before 1999.

Development of a Fish Farming Strategic Plan

Efforts to develop aquaculture in the Lake Victoria Basin started during the colonial era and continued after independence in 1961. However, aquaculture development was not supported by any strategic development plan until 2005 when a draft plan was developed. The strategy was geared towards implementing the National Fisheries Sector Policy and Strategy Statement of 1997. The strengths, weaknesses, opportunities and challenges (SWOCs) for aquaculture development in the basin were identified following a thorough review of the external and internal situations (Table 7.3). The SWOCs formed the basis for identifying the strategic issues to be addressed in a five-year strategic plan from 2005/06 to 2009/10.

Table 7.3 Strengths, weaknesses, opportunities and challenges (SWOCs) analysis

Strengths	Weaknesses
Existing National Fisheries Policy and Act	Inadequate awareness on fish farming practice to potential fish farmers
Suitable soils for fish pond construction	
Reliable sources of water	Inadequate fish farming extension services
	Lack of quality fingerlings
Reliable sources of brood stock	Inadequate facilities for fish farming
Adequate interested fish farmers	
Adequate fish farming expertise and leadership structure	Lack of transport facilities for extension workers
Availability of fertilizers for pond fertilization	Inadequate legal framework for ownership of land for aquaculture
	Poor fish pond management
	Lack of demonstration fish ponds closer to fish farmers
Adequate fish farming experience in the basin	Low fish yields amidst high expectations
	Lack of credit schemes for fish farmers
Availability of supplementary feeds	Low priority accorded to fish farming activities by fish farmers and local authorities.
Adequate knowledge of conservation of fish farming environment	
Availability of labour	Lack of quality fish feed
Availability of equipment for pond construction	
Existence of aquaculture Fisheries Training and Research Institutes	Stunted growth of cultured fish especially tilapias
	Difficulties in accessing credits from financial institutions to support aquaculture
	Inadequate capacity to promote fish farming
	Inadequate research information
	Inadequate support to research and training institutes
	Lack of gender balance in fish farming practice
	Inadequate knowledge on markets for farmed fish
Opportunities	Challenges
Favourable legal and policy environment	Unexpected changes in weather such as El-Nino floods
Availability of markets for farmed fish	Changes in government development priority due to change of government policies

(continued)

Table 7.3 (continued)

Strengths	Weaknesses
Employment for youths	Existence of fish predators and competitors such as otters, snakes, frogs, etc.
Reduction of malnutrition	
Emerging credit schemes with less stringent conditions	Theft of fish from fish ponds
	Outbreak of fish diseases
Existence of Non-Governmental Organizations and Community-based Organizations that can contribute to awareness raising on fish farming	Resource (e.g., water) conflicts between fish farmers and peasants and pastoralists
	Conflict of interest among stakeholders on water uses
Existence of government research and training institutes	Unexpected prolonged droughts
Availability of renewable sources of energy for aquaculture (windmill and solar energy)	
Increased costs of fishing	
Existence of high demand for *C. gariepinus* fingerlings for bait	
Existence of numerous small water bodies that can support aquaculture	
Existence and ability to use internet facilities by fish farmers	
Declining catches from capture fisheries and increase in human population	

7.2.7 Stocking of Small Water Bodies

A substantial number of small water bodies, referred to as public reservoirs, were constructed and stocked with different fish species in the Lake Victoria Basin during the 1950s and 1960s (Fisheries Division 1967, 1968). According to Bailey (1968) fish fingerlings were distributed to public reservoirs. Existing records only mention Malya dam in Kwimba District, Mwanza Region, which was constructed and stocked with fish during the colonial era. Kyarano dam in Butiama village, Bunda District in Mara Region was constructed in 1985 and stocked with tilapiines in 1994 by the Fisheries Development Division (E. Kilosa, pers. comm.).

Several dams in the Lake Victoria Basin were reported to have been “self-stocked” (i.e. fish entered the dams from rivers without deliberate attempts by man) by tilapiines and catfishes (Bwathondi et al. 1993, 1998; Bwathondi and Mahika 1997). Such dams include 45 dams in Mara Region, 25 in Mwanza and one dam in Kagera Region. On the other hand, deliberate efforts were made by TAFIRI to stock two dams in 1997, three dams in 2003 and 2005 all in Mara Region. Generally, there had been no deliberate efforts by the Government to put sufficient emphasis on fish farming in small water bodies, in the basin and in Tanzania as a whole.

7.3 Discussion

7.3.1 Fish Farming Potential

The results have shown that Lake Victoria Basin has the potential of increasing farmed fish production, but this potential has not been fully tapped for food production. Deliberate efforts need to be made to tap this potential through the use of improved technologies, urging the private sector to invest in aquaculture and sensitizing the farmers in the Lake Victoria Basin to practise fish farming. With an estimated 70% of Africans being both farmers and consumers of agricultural products, it has been indicated that Africa has the potential for expansion of aquaculture, which could increase production levels due to the existence of suitable climatic and physical characteristics (Brummett et al. 2008). Furthermore, about 37% of sub-Saharan Africa is suitable for small-scale aquaculture and 23% for commercial aquaculture (Brummett et al. 2008); however, less than 5% is utilized for the purpose (Kapetsky 1994; Aguilar-Manjarrez and Nath 1998).

Several factors are behind poor development in fish farming activities/business in the Lake Victoria Basin, Tanzania. These include lack of expertise due to inadequate extension services, lack of quality fish fingerings and feeds; lack of financial backing by financial institutions; and the reliance of the government on external support (Bwathondi et al. 1993; Bwathondi and Mahika 1997; Bwathondi et al. 1998; Mahika et al. 2001; Mbilinyi and Shoko 2002). In addition, most fish farmers lack self-initiative in developing fish farming while others regard it as a hobby or part-time activity (Shoko et al. 2011c).

The potential of fish farming as a source of protein and income can only be realized through proper planning, management and correction of setbacks. Fish farming practised in the basin is mostly for subsistence, which may not contribute significantly to the welfare of the people. Fish farmers should be inspired to consider fish farming as an important activity not only for protein provision, but more importantly for income generation. The Government must consider the aspect of financial and institutional arrangements for small-scale operators to benefit from this sub-sector of the economy. It has been suggested that for increased fish production from aquaculture, government policy should be geared towards the promotion of commercial investments, which can lead to future growth (Ridler and Hishamunda 2001; Hishamunda and Manning 2002; Hishamunda and Ridler 2002).

7.3.2 Culture Systems Used

From the results, it is clear that pond culture is the main culture system used for fish farming in the Tanzanian part of Lake Victoria Basin. The pond culture system is mainly semi-intensive and is practised by subsistence farmers in static earthen ponds (Shoko et al. 2011c, 2015, 2016a, b). The development of fish farming is not only measured by the number of culture systems practised but rather by the yields obtained from a particular system. Freshwater pond culture has shown great potential in East and Central Africa despite the fact that the fish yield is still low (Shoko et al. 2011c). Fish yields from ponds can only be realized through proper pond management. Shoko et al. (2011c) reported poor fishpond management in Lake Victoria Basin where most fishponds were not fertilized, and fish were not properly fed. Some fishponds were choked with grass and were completely abandoned. However, fishpond culture has proved successful in other parts of the world such as Asia (de Silva and Davy 2010).

Fishpond management can be enhanced through the integration of fish culture with other farm enterprises, particularly crop and animal husbandry (Shoko et al. 2011c). The common practice for fish farming development in Africa has been that of fishponds as a stand-alone enterprise. Fishponds have been promoted almost exclusively as a source of fish production. This has made fish farming to be considered a part-time activity, with more time being devoted to other activities, thereby seriously reducing time for tending fish. Efforts to link fish culture with other livestock production activities such as poultry and vegetables by small-scale farmers have been initiated recently in Tanzania (Shoko et al. 2011c; Limbu et al. 2016b). Fish yields have usually been poor because most of the farms were nutrient-starved, which led to the abandonment of thousands of fishponds.

The creation of awareness for fish farming communities around the Lake Victoria Basin, Tanzania, to integrate fish farming in the overall farm enterprises through integrated aquaculture-agriculture should be encouraged. Under such integration, a fishpond, which is in most cases a newly introduced enterprise, can be integrated into the on-going farm activities, relying largely on farm residues as pond inputs, especially feeds and/or fertilizers, to increase fish production. In such systems, a fishpond can have a pivotal role in supporting other activities, e.g. dry-season vegetable gardening using fertile water from the ponds, and increased crop production using pond mud to fertilize nutrient-depleted fields. Maximum fish farming production for income generation and poverty alleviation will be realized through this kind of integration.

7.3.3 Number, Size and Yield of Fishponds

The results indicated an increase in the number of fishponds in the 1960s, but the activity almost collapsed between 1970s and 1990s, and picked up again from the late 1990s to 2005 (Fig. 7.1). This trend can be explained in part by the post-colonial donor support initiatives, which failed because of top-down arrangements made between the Government and donors, typically alienating the farmers (Bwathondi and Mahika 1997; Bwathondi et al. 1998). Those initiatives collapsed after the funds were exhausted. Furthermore, during the 1970s to 1980s, low priority was given to aquaculture activities, as more emphasis was given to other sectors of the economy such as agriculture, wildlife, human settlements, and education, among others (United Republic of Tanzania 1982).

The advent of the LVEMP in 1997 made deliberate initiatives on fish farming practice. The project deviates significantly from the experience of the past, and farmers were provided with technical support and left to develop spontaneously. Since fish fingerlings were provided to fish farmers free of charge in the pilot districts, people became interested and soon the activities spilled over to other areas. This is evidenced by a significant increase in the number of ponds during this period.

Results from various studies show an increase in the yield from cultured fish over time. A study by Shoko et al. (2011c) reported a yield of 1,823 kg/ha from fishpond yields in the basin. A gross yield ranging from 2,624 ± 242 to 14,575 ± 1,658 kg/ha was obtained by Shoko et al. (2016b) for *O. niloticus* cultured in monoculture at stocking densities of three and six fish per square metre respectively. For *C. gariepinus* cultured in monoculture at stocking densities of three, six and nine fish per square metre, gross yields of 8,014 ± 75, 14,022 ± 28 and 17,175 ± 1,389 kg/ha were obtained by Shoko et al. (2016a), respectively. Such results are comparatively higher than pond yields reported elsewhere in the tropics. Bardach et al. (1972) reported that where monoculture of tilapiines such as *O. niloticus* is practiced with fertilization and supplementary feeding, yields of between 1,000 kg/ha and 2,500 kg/ha could be achieved. Mafwenga (1994) reported an average fishpond yield of 1,400 kg/ha and 1,900 kg/ha respectively from Mbeya, Iringa, Arusha and Ruvuma regions in Tanzania. The yields for the three fish per square metre stocking density are relatively comparable to gross yields of 3,649 ± 910 kg/ha for *O. niloticus* and 2,746 ± 527 kg/ha for *C. gariepinus* fed on mixed ingredients obtained by Limbu et al. (2016a) in Morogoro region, Tanzania.

Increased yields are related to improved pond management and increased stocking densities. The yield could be more improved by adopting a polyculture system of the two commonly cultured species in Tanzania (Shoko et al. 2016b). The fact that fishpond yields of the 1990s differ from the yields of the 2000s indicates that deliberate efforts should be made to improve fishpond management in the Lake Victoria basin. However, there was no correlation between the increase in the number of fishponds and the yields due to lack of data.

The size of fishponds is an important aspect in attaining maximum fishpond yields. Despite the fact that fish farming in the basin started during the colonial era (Fisheries Division 1967, 1968) yet most of the ponds were small (less than 100 m^2) which resulted in low fish yields. In their study, Shoko et al. (2011c) reported that 96% of the ponds sampled had an average area of 166 m^2, which is an improvement from the colonial era. Fish farming experience has shown that in semi-intensive farming systems, very small ponds have a negative impact on the welfare of fish.

With the current level of pond management, it is recommended that fish farmers should not construct ponds of less than 200 m^2; and the stocking density should be >3 ind./m^2, depending on the management regimes, in order to attain maximum fish yields. The ponds should be constructed in a manner that allows sunlight and heat reception in order to promote natural primary and secondary productivity. There is a slight increase in pond size over time as indicated in Fig. 7.2. Although this increase may not be significant, it is nevertheless a sign that fish farmers are shifting from small size fishponds to bigger ones.

7.3.4 Farmed Fish Species

Results have shown that both indigenous and exotic fish species have been cultured in the basin. Probably the culture of indigenous fish species in the basin was caused by the fact that Lake Victoria was dominated by those species prior to the 1980s. Indigenous fish species from Lake Victoria are a delicacy to the people of the basin, which may dictate for their preference in aquaculture (Bwathondi et al. 1998). According to FAO (1994), many indigenous fish species are preferred by consumers but have not yet been fully tested as candidate species for aquaculture.

The NFFTI conducted cage and pond culture experiments of *O. esculentus* and found it to have a positive growth. In another experiment, *T. zillii* showed positive growth under pond culture (NFFTI 1972). Moreover, *O. variabilis* showed a better growth performance when fed on cotton seed cake containing a diet other than the soya bean meal, and a feed mixed with cotton seed cake and soya beans, referred to as a composite diet (Shoko 2002). Results from studies like these, should be adopted and practised by researchers, managers and interested fish farmers. Research results could be tested in the pilot areas to assess their performance before being introduced to farmers upon success.

Studies have also showed that people from Kagera Region prefer to culture "Mbofu" *Bagrus docmac* (Bwathondi et al. 1998) whereas those from Luo land in Rorya district of Mara Region prefer "Kamongo" *Protopterus aethiopicus* (Bwathondi et al. 1993). Such fish species could be more accepted for culture by people living in those areas than any other species once their culture technologies are established. The Nile tilapia (*O. niloticus*), though exotic to Lake Victoria, is the most preferred fish species in aquaculture in the basin due to its proven high nutritive qualities. In addition, most of its culture technologies are well known. Efforts should be made to promote the culture of this species while developing culture technologies for other preferred fish species such as those mentioned above.

Presently, the African sharptooth catfish (*C. gariepinus*) is also cultured in monoculture or polyculture with *O. niloticus* (Shoko et al. 2015, 2016a, b). Moreover, its fingerlings are preferred as bait in the Nile perch fishery. The species is sourced from small water bodies such as dams and rivers. Unfortunately, *C. gariepinus* is one of the threatened fish species, which has just started to reappear in these water bodies, acting as refugia (Mkumbo and Mlaponi 2007). The culture of *C. gariepinus* will serve as a source of high quality protein and income generation for the communities through the sale of fingerlings for bait in the Nile perch fishery and fish for food.

Despite the efforts made by the LVEMP to establish fish breeding ponds for fingerlings production, the demand for the same could not be met because more people became attracted to the aquaculture venture. The government and the private sector should make efforts to establish more hatcheries, particularly of *O. niloticus* and *C. gariepinus*, in the districts where fish farming is practiced. This will reduce the costs involved in transporting fingerlings and reducing unnecessary mortality.

7.3.5 Adoption of New Technologies

Results have shown that most experimental works do not go beyond the experimental stages. Once a study is completed there are no initiatives to make sure that the results of the work are extended for adoption by farmers. Fish farming development in the Lake Victoria Basin and Tanzania in general will only be achieved through the development of simple technologies suitable to local conditions (Limbu et al. 2016a). The rapid aquaculture development in countries like China, for example, was strongly backed by development in research and technology (Hishamunda and Subasinghe 2003); Tanzania ought to do the same.

7.3.6 Extension Services

Despite the efforts made by the Government and private sector to provide extension services to farmers, general knowledge on fish farming and its management is still inadequate. Results have shown that the Government and NGOs conducted little training. A study by Mahika et al. (2001) reported a number of NGOs, which did a commendable job in fish farming extension services although their activities were uncoordinated. Shoko and Onyango (2005) report the existence of 14 NGOs, which provided fish farming extension services in the basin (Table 7.2).

Some of these organizations are so deeply rooted in the communities that it has become difficult for other fisheries extension officers to access the farmers and train them without passing through the respective NGOs. It was reported that these NGOs are playing an important role despite some observed weaknesses, which need to be corrected (Shoko and Onyango 2005). Experience has shown that a partnership that involves scientists, extension officers and most importantly, the farmers, has proven successful in fish farming development (Pullin and Prein 1995). In this partnership, farmers are given an opportunity to study, discuss and learn from each other, and then develop strategies for improvement together.

The biggest obstacle to fisheries development is inadequacy of effective fisheries extension services. In order to accelerate socio-economic development in the fishing communities, an extension programme on how to use modern methods and techniques is essential. Fortunately, the National Fisheries Policy of 1997 recognizes the importance of effective fisheries extension services and for that matter has policy statements on education, aquaculture development, community participation, and fisheries information management, among others (United Republic of Tanzania 1997).

The Fisheries Development Division started to provide effective fisheries extension services when fishers were trained at the NFFTI. The training was on engine repair and maintenance, fish handling and processing using improved methods, gill-netting, long lining and fish farming among others. This training programme was terminated in 1966 (Fisheries Division 1967). Generally, the fishers who were trained admitted that the training was useful to them. Proper training and especially the demonstration of improved fishing methods, fish handling and processing will improve efficiency and increase income for the riparian communities.

7.3.7 Stocking of Small Water Bodies

Fisheries in small water bodies usually operate at a basic level and could provide opportunities to supplement the diets of poor people/families. Results have shown that there were some efforts to stock smaller water bodies, referred to as public reservoirs, during the 1960s. Although reports do not show the exact number of these reservoirs, the available information show that fish yields and income were generated from these waters (Fisheries Division 1967, 1968).

Observations have shown that there are several dams in the Lake Victoria Basin, which can be used for aquaculture under simple management techniques. The same can be done for temporary dams, where fish would be harvested before the commencement of the dry season. The communities should be taught how to properly protect these dams for the sustainable management of the fishery resources within them. Such efforts can provide fish and income to the riparian communities.

7.4 Conclusion

All things considered, it is clear from the available data, that the fish stocks of the three commercial fish species, namely *L. niloticus*, *O. niloticus* and *Rastrineobola argentea* are heavily exploited, primarily due to high demand in both domestic and foreign markets. This situation, coupled with the high levels of poverty in the Lake Victoria Basin, has only served to highlight the importance of fish farming as an alternative source of protein and income for the riparian communities. Fish farming can help to reduce fishing pressure on capture fisheries and contribute significantly to the conservation of the lake's biodiversity. Ultimately, fish farming will generate income for the people, which is in line with the government's efforts to alleviate poverty in the country.

The Lake Victoria Basin has great potential for fish farming development, which unfortunately, has not been tapped for food production. Fish farming in Lake Victoria Basin has not developed significantly because the constraints that have been reported since the 1960s have not been fully addressed. Currently fish farming is carried out mostly for subsistence, which cannot contribute adequately to the welfare of the people.

7.5 Recommendations

Based on this review, the following recommendations are made:

- Data on fish farming activities should be gathered and submitted to the Fisheries Headquarters by district fisheries officers every 3 months. Specifically, the data should be on the following: (a) the number and size of stocked fishponds; (b) fishpond yields and the income generated; (c) the number of men and women participating in fish farming; and (d) the types and amount of fertilizer and fish feeds used.
- Detailed basin-wide surveys/inventories on fish farming activities should be conducted every year.
- Fish farmers should be encouraged to keep records of inputs and the outputs of their farms for ease of monitoring and planning.
- There should be close government supervision (provision of technical support) through frequent visits to farmers.
- More community-based fish breeding hatcheries should be established in potential districts for the provision of fish fingerlings to farmers. Such fingerlings should be sold to farmers at affordable prices.
- Emphasis should be directed towards an IAA in order to raise overall farm yields (i.e. fish, crops and/or tame animals).
- Joint researches should be conducted by institutions, NGOs and fish farmers.
- The farming of *C. gariepinus* should be promoted in order to produce live bait for Nile perch fishery and to produce food for the people. The production of *C. gariepinus* will also reduce the exploitation of wild stocks.
- In collaboration with the Department of Aquatic Sciences and Fisheries Technology of the University of Dar es Salaam (UDSM), Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, and TAFIRI, the government should establish a national modern hatchery for aquaculture research and development. Fish farming stakeholders such as local government authorities, universities, NGOs and CBOs should internalize the Fish Farming Strategic and Development Plan so that it can be successfully implemented. On its part, the government should use this plan to promote fish farming in the country.
- The government also needs to accept the fact that science and technology are the most important drivers of the economy and provide funds for the development of aquaculture technology that is suitable to the Tanzanian environment. Besides, the government should regard the small water bodies in the country as potential areas for aquaculture. All the dams should be stocked with fish for consumption

and income generation by the people living around or near them, and should be managed using simple management methods. Finally, an assessment of the impact of the decrease in water levels in Lake Victoria on aquaculture should be conducted.

- Efforts on extension services should be continued in order to reduce the loss of income due to poor fish handling and processing methods, inadequate dissemination of information, absence of fishers' associations and inadequate market information, among others.

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Chapter 8
Socio-economic Characteristics of the Lake Victoria Fisheries

P.O. Onyango

Abstract This chapter presents a synthesis of socio-economic characteristics of Lake Victoria fisheries. This is discussed by examining changes in indicators such as employment, education and/or literacy levels, age structure, incomes and contribution to the national economy. In addition, analyses on fishing equipment used, fish trade, industrial processing, fish prices, per capita consumption, diseases, gender dynamics and contribution to Gross Domestic Product and incomes are presented. This work is based on over 20 years of data collected on the lake's fisheries. Results indicate that the lake's fisheries have generated substantial socio-economic benefits for both the fishers and the exchequer. This is evidenced in the level of employment, which has doubled between 1993 and 2000 and is still increasing. The income generated has remained at the level of over 2 billion Tanzanian shillings (over USD 100 million) between 1996 and 2011. Individual fishers have also been earning between USD 100 and 400 annually. The chapter also presents the types of gear that have been used since 1900. It also discusses the fish species processed and traded. Essentially, it concludes that the lake's fisheries remain an important socio-economic resource for the riparian states and communities.

8.1 Introduction

This chapter presents the socio-economic characteristics of the Lake Victoria fisheries. It indicates how the fisheries have remained important to both the riparian communities and states. In particular, the chapter examines changes in the socio-economic indicators such as employment, education, age structure and income contribution to the national economy among others. Other areas the chapter discusses are gender, stakeholder perceptions and expenditure. The chapter examines how the micro- and macro-changes in the fisheries through time, have affected fishers in particular and

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their communities in general. It therefore generates an understanding about fishermen, processors and traders, fishing gears, markets and prices, demographic characteristics, diseases and the fisher's incomes and perceptions on the status of fish resources.

Since over 400,000 years ago, several communities have depended on the fish resources found in the lake (Johnson et al. 2000). In fact, these communities have interacted with the lake for so long that it has become part and parcel of their lives. To some of these communities, fishing is a way of life (Onyango 2011). Thus, ensuring a sustainable fishery can be achieved if there is an understanding of these communities' socio-economic characteristics.

Since the 1900s, several studies have been undertaken in the fisheries of the lake. Some of these studies have focused on the socio-economics of the fishing communities and the impacts that the fisheries have had on them. These studies have shown that there are several rivers that flow into Lake Victoria which are ecologically, biophysically, culturally, and socio-economically important to the development of the shoreline catchment area and of the people who live on the islands.

The studies have revealed that agriculture and fishery are the main economic activities that are undertaken in and around the lake. Fisheries have received reasonable attention for the reason that they contribute between 0.5 and 3% to the Gross Domestic Product (GDP) of the economies of riparian countries (Kulindwa 2005). Moreover, they play an important economic, social and cultural role to the riparian communities, namely the Kuria, Simbiti, Sukuma, Haya, Kerewe, Luo and the Jita (SEDAWOG 2000), who depend on them.

Historically, the Kerewe, Sukuma, Luo and the Jita are known as the lake's fishing communities (Geheb 1997; Onyango 2004). They have been fishing from the lake since time immemorial; their own history can also be associated with fishing. Other communities joined the fisheries much later in history but have since made fishing a major community activity. Mining and tourism are the other important economic activities that these communities engage in; with gold mining in Geita and Nyamongo and tourism in Serengeti and Rubondo Island National Parks where the rich wildlife resources are renowned tourist attractions.

8.2 Basic Fishery Information in Tanzania

In Tanzania, the main fishing water bodies are the Indian Ocean and the lakes Victoria, Tanganyika and Nyasa. Others include several rivers such as Rufiji, Pangani, Mara and Kagera among others. There are also several dams and ponds. Most of the fishes are caught from the freshwater bodies by artisanal and/or small-scale fishers. Lake Victoria produces more than 60% of the total annual amount of fish produced from inland waters.

Artisanal fishery is characterised by use of small canoes, rafts and plywood boats (Plateau, cited in Bagachwa et al. 1992). In general fisheries in the country are carried out at a small-scale level. Previously, there used to be commercial fishing of prawns in the Indian Ocean. However, due to reduction in stocks, commercial fishing of this species was stopped between January 2008 and April 2017. There has also been industrial fishing in Tanzania for example, trawling in the lake, which was present up to the mid-1980s (ESAURP 1987, cited in Bagachwa et al. 1992). This fishing method and beach seining have been banned since the mid-1980s. Today, trawling is done in the lake for research purposes only (Fisheries Development Division 2005).

8.3 Socio-economic Indicators of the Lake's Fisheries

8.3.1 Employment

Lake Victoria fishery is a source of employment to a substantial number of people, including fishermen, fish processors, fish traders, and boat makers, gear repairmen, and other service providers such as restaurants, guesthouses, health, food supply and suppliers of construction items just to mention but a few. Since the 1950s, the fisheries have provided direct employment to fishers. Records indicate that as from 1968, the fisheries have provided direct jobs to fishers from 20,000 to over 100,000 in 2012 (Fig. 8.1). The number has been and continues to increase. The trend line shows a very strong correlation ($R^2 = 0.77$ and $r = 0.88$) in the increase of the number of fishers with time (Fig. 8.1).

However, the fisheries have also provided indirect employment through backward and forward linkages. Kulindwa (2005) estimated this employment to have risen from 35,291 in 1993 to 87,821 fishers in 2000 (Fig. 8.2). Kulindwa's estimation was based on the lake's fishery and industrial employment data. Similar data have since been amalgamated with agriculture and forestry. However, Fig. 8.1 shows an increasing trend implying that the subsequent year's employment was higher.

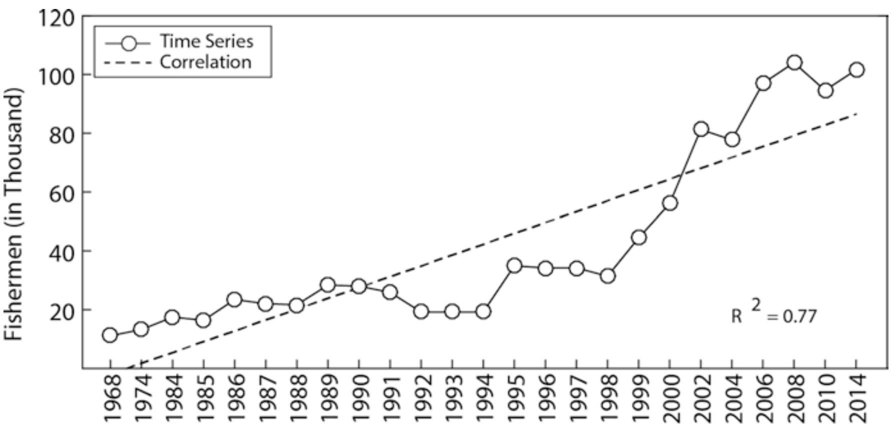

Fig. 8.1 Graph showing number of fishers in Lake Victoria between 1968 and 2012 (Data from Ministry of Agriculture, Livestock and Fisheries)

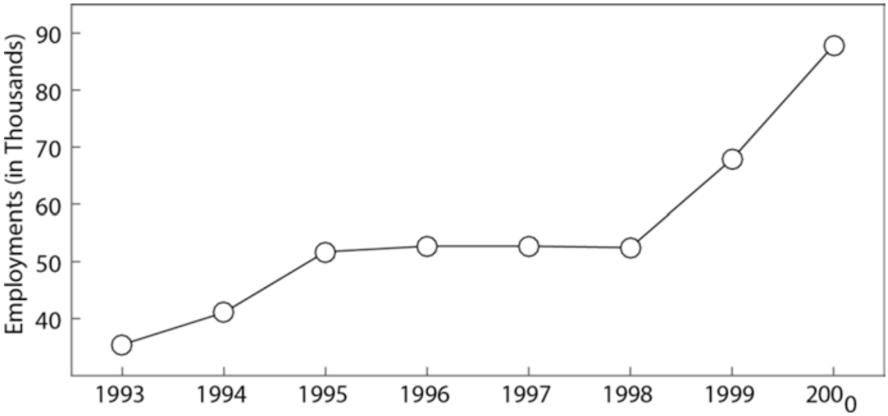

Fig. 8.2 Trend of employment in Lake Victoria fisheries 1993–2000 (Redrawn from Kulindwa 2005)

Over the years, it has been estimated that on the Tanzania part, Lake Victoria is a direct source of bread to about 500,000 fishermen, fish traders, fish processors and "net menders" (Odongkara et al. 2005). However, this is regarded as a gross underestimation of the employment because we estimate that 1 kg of fish that is processed locally is handled by between 8–13 people (see Box 8.1). Therefore, working with an average annual production of about 200,000 mt, it is estimated that the lake has created over 2.6 million jobs (Box 8.1 and Table 8.1).

The fisheries create employment for fishers, through fish processing and selling, net and boat making and repairing. Some of them serve as porters. But in the fishing villages there are a number of people who have opened businesses ranging from drug shops, food stores, and barbershops, bars and restaurants and other auxiliary jobs.

8.3.2 Age Structure

The majority of Lake Victoria fishermen are in the labour force age group. This indicates that fishing activity attracts labour just like other sectors. The youngest fisherman ever recorded was aged about 12 years old and the oldest was about 79 years old (Onyango 1999). A scrutiny of the population structure of the lake indicates that it doesn't deviate much from the national structure except that there is a younger population in the fishing sector than could be the case in other sectors. However, this could also be explained by the fact that the country's population is generally young (United Republic of Tanzania, URT 2010 census report).

Box 8.1: The Number of People Involved in Handling a Kilo of the Nile Perch in Lake Victoria

One kilo of the Nile perch is handled by between 8–13 people, as described below. On average, there are four licenced fishermen per boat. When the fishermen have landed the fish on the shore, a porter takes it to a waiting truck. At the truck, there are three people: one person weighs the fish and takes records; another person puts it in the truck; and the third person is the truck driver. Besides these, there are also the people who offload the truck at the factory, the people who clean the hut where the fish is weighed, the people who mend nets, the people who repair boats, the people who supply bait. As far as locally processed fish is concerned, there are women who purchase the fish from the fishermen. In turn, the women either sell it to a processor(s) or process it themselves and then sell it to traders. Other people do research and management work. In summary, the people engaged in handling a kilo of fish is as summarised in Table 8.1.

Table 8.1 Estimation of employment in Nile perch fisheries of the lake

Fisher category	Number
Fishers in the boat	4
Boat repairer	1
Gear repairer	1
Porters	1
Weight takers	1
Truck loaders	2
Truck Driver	1
Off loaders	2
TOTAL	**13**

Source: Author's own estimation

Table 8.2 shows the population structure in terms of age groups. The data are taken from Kilosa et al. (2004), Leendertse (1993), TDHS, TKAPS, TDHS and TRCHS. From Table 8.2, the first two columns show percentages from the lake basin. The rest of the columns are national census surveys as well as demographic household surveys taken at different times. The information indicates that in the country, half of the population is less than 15 years and about another half is between 15–60 years. The fishing sector nonetheless shows a different picture. A young population aged between 15–40 years dominates fisheries.

Table 8.2 Percentages on the population of fishermen in broad age groups

Age group (years)	References									
	Kilosa et al. (2004)	Leendertse (1993) [Kagera]	Population census			TDHS[a]	TKAPS[b]	TRCHS[c]	TDHS	National Bureau of Statistics
			1967	1978	1988	1991–2	1994	1999	2010	2014
<15	0	31	43.9	46.1	45.8	46.8	49.3	46.8	47.4	43.9
15–60	39	63	50.5	49.9	49.9	49.3	46.4	49.1	46.6	51.3
>60	61	2	5.6	4	4.3	3.9	4.3	4.1	6.3	4.8

[a]Tanzania Demographic Household Survey
[b]Tanzania Knowledge, Attitudes and Practices Survey
[c]Tanzania Reproductive and Child Health Survey

Table 8.3 The level of education

	Source					
	a	b	c	d	e	f
Educational level	Percentage					
Primary	66	82.4	82.1	70.8	88	84
Secondary	12	12.3	11.2	7.1	12	7
College	1	0.5	0.4	1.6	0	0.9
None	11	4.6	6.3	20.5	0	8
Informal	0	0.2	0	0	0	0

Source: a = Leendertse (1993; Kagera), b = Kulindwa (2005), c = Kisusu and Onyango (2003), Muro et al. (2005), d = Kilosa et al. (2004) and e = Onyango et al. (2006)

8.3.3 Literacy Rate Among Fishers

Table 8.3 indicates that the level of education for most fishers is low. It also shows that some of the people who engage in these activities are not very well educated. On average, about 78% have attained primary level education. Very few have any college education.

The literacy levels is a very useful information in identifying where to build capacity of fishers. Moreover, education is vital in cases where new technologies have to be used. It is assumed that with higher education, adoption of new technology will be quicker. However, the current level of education can be hypothesised to be a reason why fishers have always been perceived as slow to change. They have clung to their old ways because their minds have not been subjected to exposure. This should not be understood to imply that they do not have any abilities or unique skills.

The number of people who engage in fishing and fishing-related activities are young (see Table 8.2) and their highest levels of education have been changing. In the 1990s, about 66% of the people in question had primary education, but about 80% had primary education in 2000. This means that the number of people who engage in fishing and fishing-related activities with primary education has been growing.

8.3.4 Fishing Equipment: Number and Types

Various types of fishing gear have been used for fishing for a very long time in the lake. The common ones have been the traditional gears such as, trawl nets, gill nets, hooks/long lines, beach seines, dagaa seines and lift nets. Gill nets were initially made from sisal fibre and later from nylon. Beach seines have traditionally been made from banana ropes and were very popular when they were introduced in the Sesse islands and then later brought to Ukerewe (Onyango 2004). Beach seines have remained a popular gear although they have been illegal since the 1980s. This is due to the fact that the gear is perceived by the local communities as promoting unity and enabling them to come and fish together. Table 8.4 shows the gear and the years in which the gear was used.

Table 8.4 and Fig. 8.3 show that outboard engines, hooks and gill nets are the oldest gears, which are still used for fishing. It should be noted that the intensity of using these gears has emerged strongly due to the Nile perch proliferation from mid-1980s.

Among the riparian communities, fishing gear was not accepted for the mere fact it could be used to fish. To these communities, fishing together was more cherished than individual fishing. Whatever tool or equipment or function that enabled them to come together was readily accepted. Therefore, fishing gears such as beach seines and gillnets have remained popular. However, since non-historical fishing communities joined the fisheries with the objective of maximising rent from the fisheries, individual fishing practices has been growing. The change of gear from gillnets to trawlers (Fig. 8.3) and then to long lines and drift nets was as a result of a few fishers wanting more fish than the others rather than taking what is enough as was the case in the traditional communities.

Boats, gillnets and beach seines have been used in the lake for a long time. Dagaa seine nets have been increasing since the 1980s while trawl nets have disappeared since the mid-1980s. Scoop nets and lift nets have been declining since the early 1990s (Fig. 8.3). The use of hooks (long lines) also grew from 296,500 in 1968 to 6,376,641 in 2012. Hooks are used much more now than they were in the past because they are cheap and able to catch more fish than gill nets.

Different types of boats have been used in the lake. They include dugouts, Karua, Sesse and Taruma. A description of these boats and others is given in Table 8.5 (see also Hoekstra 1992; Witte and Densen 1995).

These types of boats indicate that the lake's fishery is predominantly small-scale. Since the 1970s, however, engines have been used to propel the boats. It is also worth mentioning that rafts and dugout canoes were the earliest vessel types to be used in the lake. Later, fishers started using Sesse and Karua canoes in the shallow waters. They then ventured into deep waters by the use of Taruma canoes.

Boats are made specifically for the type of fishing it will be used for (Table 8.5). Sesse canoes are made for fishing Nile perch except for Sesse canoes, which are pointed at both ends; these are used for dagaa fishing.

8.3.5 Fish Trade

In Lake Victoria, fish were initially caught for household consumption and for small-scale barter trade. In some cases, fishermen gave some fish to the people at whose homes they were staying so that they could not be chased away or be fought (Onyango 2004). Processing was essentially smoking. However, proliferation of Nile perch in the Lake Victoria has caused changes in processing and trade. The

Table 8.4 Types of fishing gear and the years in which they were used in Lake Victoria

	Type of gear										
	Traditional gears	Trawl nets	Gill nets	Hooks/long lines	Beach seines	Scoop nets	Dagaa seines	Lift nets	Drift nets	Rafts	
Before 1990	x			x	x	x					Garrod 1960 quoted in Geheb 1997
1900											
1900	x		x	x	x	x					Worthington and Worthington, 1933
1920	x		x	x	x	x					
1940	x		x	x	x	x					Fisheries Annual Statistics
1960	x		x	x	x	x					Fisheries Annual Statisitcs
1980		x	x	x	x	x	x	x			Fisheries Annual Statistics
2000		x	x	x	x	x	x	x	x	x	Frame Survey, 2000
2005		x	x	x	x	x	x	x	x	x	Frame Survey, 2004
2010			x	x	x	x	x	x	x	x	Frame Surveys, (2008, 2010, 2012)

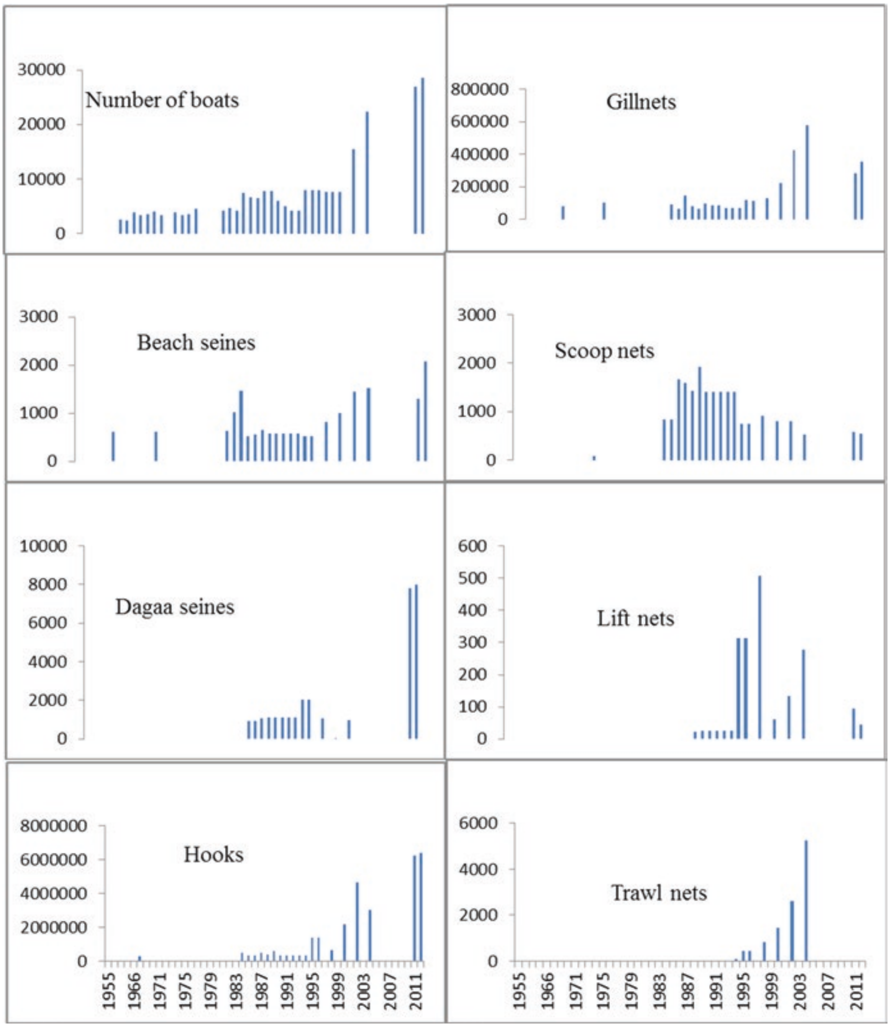

Fig. 8.3 Changes in fishing gears between 1955 and 2012 (Source: Fisheries Development Division Statistics)

lake's fisheries, which were originally dominated by cichlids became predominated with Nile perch (see Table 8.6).

For a long time, fishing in the lake by the riparian communities was basically for domestic consumption. The marketing campaigns of the early 1970's did not have a significant impact on Lake Victoria fisheries. It was not until the establishment of trawl fisheries and the related industrial processing of Nile perch for export market that trade opened up in the fisheries of the lake. During and after the proliferation of the Nile perch, new processing techniques such as smoking with kilns, salting and sun drying became quite predominant.

Table 8.5 Types of boats used in Lake Victoria

S/No	Boat type	Boat type description
1	Dugout canoe	A boat carved out of a log of wood (tree trunk). It has neither joints nor planks. Curved out of a whole log of a tree. Common size measures 4 to 5 m long.
		It is entirely propelled by paddle and operated exclusively in the littoral areas targeting Nile tilapia and lung fish. The main fishing gear used includes gillnets, basket traps and hooks.
2	Sesse (Pointed both ends) canoe	A modified dugout canoe, pointed at both ends. The bottom is V-shaped. The sides are made of planked wood. Constructed from planks of timber. It has a V-shaped bottom with a keel. The length ranges from 6 to 10 m long and it is propelled by paddle or sails. It is also operated in the littoral and sub-littoral areas, up to about 3 km from the shore. Used to target dagaa fishery with small seines; in the Nile tilapia fishery with gillnets, cast nets and basket traps; and in the Nile perch fishery with gillnets, beach seines, long lines and hand lines.
3	Taruma	An improved Sesse canoe. The bottom is V-shaped. It is mostly used in deeper waters because of its stability. It is made of planked wood and can be modified for use by an outboard engine. Constructed from planks of timber. The length ranges from 5 to 12 m long and is propelled by paddle, sail or out board engine. It is used for dagaa fishing with small seines, Nile tilapia fishery with gillnets, cast nets and basket traps; and Nile perch fishery with gillnets, beach seines, long lines and hand lines.
4	Karua	It has a flat bottom. It is made of planked wood and is mostly used in shallow waters.
5	Raft	It has a flat bottom and is made from reeds (Phragmites karka). It is used for fishing tilapia. It measures between 2 and 3 meters long. It can only accommodate one person. It is used in very shallow areas to fish Tilapia.

Source: Author's observation

Only small-scale fish processing and trade is done for income generation by women. Currently, this is their main economic activity, although other goods were also sold in the past along with it. Prior to the establishment of industrial fish processing in the early 1990s, smoking was the main method for fish processing used at the huts on the shore. Although this method is not used much nowadays, it has, like boat building, caused a substantial quantity of trees to be cut down on a number of islands, leading to deforestation and environmental degradation. Moreover, processed fish is carried in baskets that are made from macrophytes, grass and shrubs further threatening the environment. As the volume of fish trade grows, a lot of macrophytes, grass and shrubs are cut from the shore, leading to environmental degradation, too.

Table 8.6 Fish species processed and traded after 1982

Year	Indicator			Source
	Species traded in	Marketability	Processing	
Before 1982	*Haplochromis*	Poor	Sun drying and smoking	Nyholm and Whiting (1975); Dhatemwa (1982) and Onyango (2004)
	Synodontis victoriae			
	Bagrus docmak			
1988	*Haplochromis*	Poor	Sun drying and smoking	Reynolds and Greboval (1988)
	Tilapia			
1990	Nile perch	Gaining momentum	Smoking	Maembe (1990)
	Dagaa		Sun drying	
	Tilapia			
1993	Nile perch	Intensive	Smoking	SEDAWOG (1999)
	Dagaa		Sun drying	
	Tilapia		Frying	
1999	Nile perch	Very intensive	Industrial	SEDAWOG (1999)
	Tilapia		Sun drying	
	Dagaa		Salting	
			Smoking	
			Frying	
2000	Nile perch	Very intensive	Industrial	
	Tilapia		Sun drying	
	Dagaa		Salting	
			Smoking	
			Frying	
2005 onwards	Nile perch		Industrial	Fisheries annual statistics
	Tilapia		Sun drying, smoking	
	Dagaa		Industrial	

SEDAWOG Socio-economic Data Working Group of the Lake Victoria Fisheries Research Project

8.3.6 Industrial Processing

Besides the artisanal processing and small-scale fish trade done by the riparian communities, the Nile perch and dagaa are also processed in industries and exported. The most exported of these is the Nile perch, whose belly flaps, fillets, chest, frames, maws, offal, skin, head, gut, chips, steak, off-cuts, kayabo, oil, carcass, etc. are exported nearly every day. Fillets are the most exported of all the items (see Table 8.7). This is followed by belly flaps, fishmeal and maws. The export of belly flaps has grown from 4,667,216 kg in 1997–1998 to 25,475,605 kg in 2002–2004. However, the export of most of the items varies from year to year. Dagaa, which was not exported before is now being exported.

The products or items in Table 8.7 are exported to Europe, Australia, Asia, Africa and America. But most of them are exported to Europe, except in 2000 when the

Table 8.7 Fish and Fishery Products exported between 1997 and 2012 (in Kg)

Product	1997–1998	2000–2001	2002 and 2004	2011	2012
Belly flaps	4,667,216	4,757,827	25,475,605	66,500	5000
Dried fish	274,436	12,050.70	5495	27,505	
Fillets	59,477,052	62,229,074	30,361,734	20,901,529	21,519,974
Fish chest	0	0	362,199	72,000	256,050
Fish frames	510,472	966,702	484,704	2,180,715	2,592,496
Fish maws	1,417,291	2,695,496	2,326,797	948,408	1,509,614
Fishmeal	1,766,377	5,763,555	2,094,650	308,000	300,008
Fish offals	394,967	1,171,660	222,870		
Fish skin	0	0	1,043,844		
H and G	20,000	1,769,426	2,467,728	1,222,721	1,545,308
NP chips	110,204	0	6200		
NP steak	0	0	200	8	
Off cuts	497,152	144,720	334,737	537,829	775,995
Kayabo	0	43,650	17,615	27,500	35,650
Fish oil	121,220	0	0	2600	200
NP carcass	456,080	0	0		
Fresh fish/whole				26,000	300
Dagaa				6,229,818	454,678
Clarias					1420

Source: Fisheries Development Division. *NP* Nile perch, *H* and *G* whole head and gutted

highest amount was exported to countries within Africa (see Fig. 8.4). In 2000, fish exports to Europe were banned and that is why the highest amount was consumed within Africa. Of course, Africa is the second highest export destination, with Kenya and the Republic of South Africa leading the others. There are several European countries to which the fish from Lake Victoria is exported. Gibraltar led other European countries twice in 1997 and 2001; Poland did so once in 1998, Portugal in 1999, Netherlands in 2002 and Italy in 2004. Japan and Hong Kong are the leading Asian markets for the Nile perch from Lake Victoria. Exports have however been declining as from 2008 (see Fig. 8.5).

It should be noted that the fish that are exported to Kenya and Uganda are re-exported to Europe. The fish are exported to the two countries because the countries have fish processing companies that are sister to those in Tanzania. Thus, the companies in these three countries export fish to Europe as one consignment.

8.3.7 Fish Prices

The price of fish from Lake Victoria has generally been low. Before the proliferation of the Nile perch, fish was sold in terms of pieces; one piece of fish was sold at an average price of Tshs 0.6 (less than US$ 1) in the 1960s. But when the Nile perch

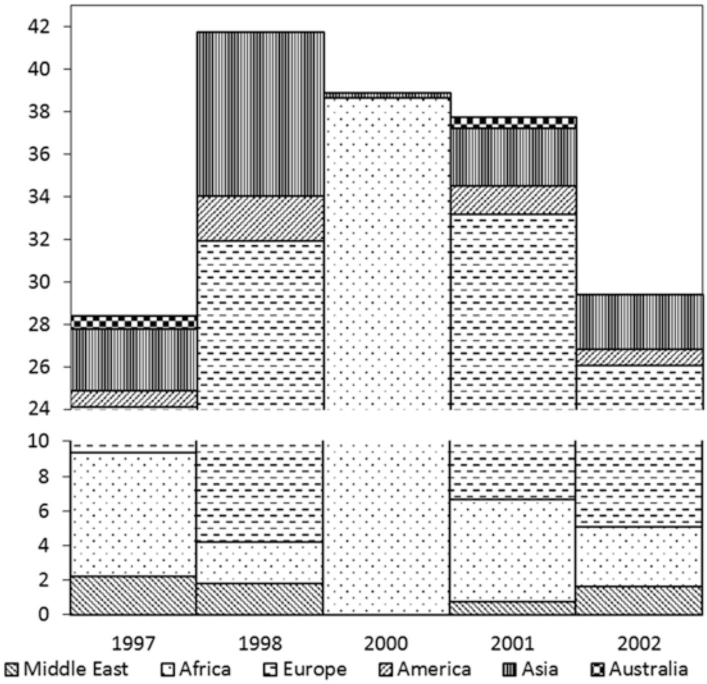

Fig. 8.4 Comparison of export of the Nile perch to six destinations between 1997 and 2004 (Data from Fisheries Development Division)

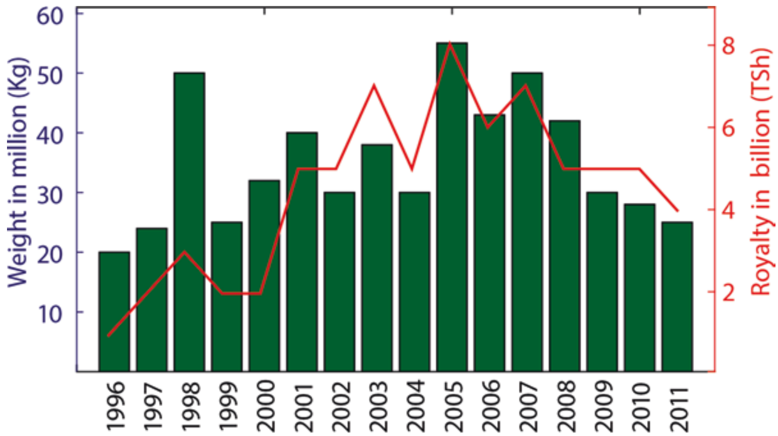

Fig. 8.5 Nile perch Export and Royalty Trend between 1996 and 2011 (Data from Fisheries Development Division)

catches rose, the prices increased, too. However, prices have remained generally low. Towards the end of the 1990s and the beginning of the first decade of the twenty-first century, the prices rose to Tshs 1000 (US$ 1) per piece and remained at that level for a long period of time. Between 2000 and 2010, prices rose in quantity but the low value of the shilling did not lead to any meaningful changes in the prices. One other observation that has been made about fish prices is that they have remained inelastic despite the changes in the amount of fish supplied (Reynolds and Greboval 1988). The prices in question have hindered development of individual fishermen, because they are lower than the prices of other natural resources (for example Gold and Tanzanite) exploited by local people.

8.3.8 Per Capita Fish Consumption

There is no data on the per capita fish consumption among the riparian communities. However, some nutrition studies reported that fish was consumed on average about 8 times a week. In other words, fish was eaten at least in one meal every day (Onyango 2003). The consequence of this has been lower malnutrition levels than the national levels (Medard et al. 2002; Onyango 2003). Data gathered by FAO indicate that the contribution of fish as animal protein to the Tanzanian population was somewhat stable between 1976 and 2001 (see Table 8.8).

8.3.9 Diseases

Diseases are among the major problems that face Tanzanian riparian communities. The main diseases include, but not limited to, intestinal parasites, Human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS) and malaria. It is reported that eight, out of the ten known intestinal parasites of medical importance in Tanzania, have been prevalent in the Lake Victoria riparian communities in the last decade (Ministry of Health Reports 2002). Seven of these

Table 8.8 The contribution of fish to animal protein for human beings

Year	Per cent
1976–1978	34.4
1979–1981	31
1982–1984	32.8
1985–1987	35.6
1988–1990	38.3
1991–1993	31.3
1994–1997	32.6
1998–2001	31.8

Source: FAO database

Table 8.9 Prevalence of intestinal parasites and schistosomiasis in Lake Victoria riparian communities

Intestinal parasite	% Total	% Kagera	% Mwanza	% Mara
Schistosoma mansoni	43.7	17.2	59	54.7
Hookworm	28.4	27.1	37.7	19.8
Ascaris lumbricoides	14.6	41	2	1
Trichuris trichiura	12.7	38	0.4	0.2
Strongyloides stercoralis	4.2	1.7	6.2	4.9
Entamoeba histolytica	21	29	19.3	14
Giardia lamblia	4.8	6	2.8	5.4

Adapted from Muro et al. (2005)

are endemic (Muro et al. 2005) and their prevalence is shown in Table 8.9. Malaria, for instance, is a serious health problem in Sub-Saharan Africa. It is estimated that about 300 to 500 million people are infected with malaria and 2–4 million people die of this disease worldwide every year. The disease situation in the lake region especially with respect to malaria remains challenging to the health authorities.

In 1990s, malaria (10.8%) and respiratory diseases (10.8%) affected a large number of people in Sub-Saharan Africa. In Tanzania, malaria is a major health problem in terms of morbidity and mortality, particularly among pregnant mothers and children under the age of five years (Ministry of Health 2002).

Accurate records on malaria are hard to come by and the data available in health centres/facilities is not very reliable because many people treat malaria at home and the drugs used to cure the disease are available in countless, private drug shops. There are numerous deaths caused by malaria that are not reported. Out of the four *Plasmodium* spp., which cause malaria, i.e. *P. falciparum*, *P. vivax*, *P. ovale* and *P. malariae, P. falciparum* is the most common in Africa.

Muro et al. (2005) reported that there was an overall malaria prevalence of 11.7% in the riparian communities. They note that there is no significant difference in the infection rate between men and women. However, the prevalence of 20.7% among children under the age of five years is the highest. Those who are aged between 45–49 (2%) and 35–39 (3.1%) are the least affected.

HIV/AIDS is recognized as a national disaster in Tanzania. According to the World Health Organization (WHO), Tanzania had 2.2 million people living with HIV/AIDS (WHO, cited in Muro et al. 2005). The number of people who were reported to have AIDS in Tanzania was 109,863 in 1986 and 549,315 in 1998. The magnitude of the disease varies from place to place within the country. For instance, in Mwanza region, there is more HIV prevalence in urban areas (7.7%) than in rural areas (3.8%) (Grosskurth et al. 1995). The fishing villages are highly vulnerable because of the daily cash flow. Since HIV infection is largely through sexual intercourse, an understanding of sexual behaviour is important in designing and implementing appropriate interventions.

There is a wide knowledge about sexually transmitted diseases such as HIV/AIDS among the riparian communities. About 99% of the members of these communities have heard about HIV/AIDS. Out of these people, 89.3% are aware that HIV/AIDS is spread through sexual intercourse. However, about 54.8% say that people can contract the disease if they use needles/injections contaminated by the blood of a person who is suffering from HIV/AIDS. There are, however, some misconceptions among the people in Sengerema district on how one can contract the disease. Such people believe that hand shaking and any other form of (body) contact with an infected person can cause one to contract the disease. Moreover, in the riparian communities, about 93.8% people are aware that condoms are available in their communities, although only 69.4% believe that people use condoms to protect themselves against the disease. In addition, 98% of the adults in the communities believe that condoms can protect one from HIV/AIDS.

The people's perceptions about HIV/AIDS, particularly with regard to transmission and prevention, have changed in the recent years. In 1996, over 30% of the people in the riparian communities believed that one could not protect oneself from HIV/AIDS, while in 2004 only about 13% had this belief. There are people in Tanzania who still hold this belief.

An overall assessment of health facilities in Tanzania reveals that 45.5% of all the health facilities in the riparian communities can offer nearly all kinds of health service. All essential types of medical and delivery equipment were available in all the health facilities and were in good condition, except for the screens, sphygmomanometer and adults and children weighing scales. Information on the health personnel found in the health facilities is summarized in Table 8.10.

Table 8.10 The proportion of health personnel in health facilities of selected riparian villages

Health personnel cadre	% Health facilities with a particular kind of health personnel (N = 11)
Clinical personnel (AMO, CO, ACO)	100
Trained nurses (Nurse MWs, PH nurses)	63.6
Medical attendants (Assistant nurses)	100
Laboratory assistants	18.2
Trained microscopists	27.3
Health officers or health assistants	27.3
MCH Aid nurses	45.4

Source: Muro et al. (2005). *AMO* Assistant Medical Officer, *CO* Clinical Officer, *ACO* Assistant Clinical Officer

Table 8.11 Men and women's participation in fishing activities

	Male	Female
Fishing (%)	99.5	0.5
Processing (%)	54.7	45.3
Trading (%)	88.1	11.9
Total	86.6	13.4

Source: Onyango (2006)

8.3.10 Gender Dynamics in Fishing

The people who live in the Lake Victoria Basin are about 10.3 million and their annual growth rate is 2.6% (www.nbs.go.tz). Specifically, the people live in the regions of Mara, Simiyu, Mwanza, Geita, and Kagera. Men constitute 49% and women 51% of the total population. In addition, about 85% of all the people in the regions above live in the rural areas. Of this, 70% are women who are smallholder farmers. Women also engage in fishing, "services" and, to an extent, in mining activities. In the fishing sector, most women engage in fish processing and selling (see Table 8.11). These data are from Kisusu and Onyango (2001).

But women have all along been excluded from decision-making processes. Because of this, a policy has since been formulated to ensure that there is 30% representation of women in virtually any fisheries institution right from the beach level (see LVFO 2010).

8.3.11 Stakeholders' Perceptions on the State of the Fisheries

A summary of stakeholders' perceptions on the state of Lake Victoria fisheries is given in Table 8.12. For example, researchers recorded overfishing of the tilapiine species, which resulted in the decrease in their catches and a subsequent increase and dominance of non-cichlids in the landings (Okeyo-Owuor 1999). The number of haplochromines also decreased. However, in the 1970s and 1980s, the haplochromines species decreased dramatically. Although the stakeholders had similar opinions on these issues, they differed with each other on a number of other issues that are presented in Tables 8.13 and 8.14. Perceptions by these groups, especially in the common areas that they had common opinion assisted in the design and establishment of a co-management regime for the lake's fisheries.

8.3.12 Contribution to Gross Domestic Product (GDP)

The lake is reported to generate about US$ 3 to 4 billion annually (Odongkara et al. 2005). Kulindwa (2005) estimated that the contribution of Nile perch to the GDP, which is based on a ratio LVFC = FI/GDP (where LVFC = Lake Victoria fishery

Table 8.12 Perceptions of fishermen, researchers and government officials on the state of the fisheries

	Indicator (Perception on the state of the fisheries)	Source		
		Fishermen	Researchers	Government officials
1900–1910	Fishing perceived as a source of livelihood	Worried about the decrease in Tilapia sizes		Geheb (1997)
1911–1920	Fishing perceived as a source of livelihood	Very happy about the species diversity (over 500 species of cichlids)	Concerned about exploitation of fish	Okeyo-Owuor (1999) Ligtvoet et al. (1995a, b) Graham (1929)
1921–1930	Fishing perceived as a source of livelihood	Very happy about the species diversity (over 500 species of cichlids)		Okeyo-Owuor (1999) Ligtvoet et al. (1995a, b)
1931–1940	Fishing perceived as a source of livelihood	Very happy about the species diversity (over 500 species of cichlids)		Okeyo-Owuor 1999 Ligtvoet et al. (1995a, b)
1981–1990		Worried about the ecology of the lake, fish diversity decline and eutrophication	Worried about sustaining incomes generated from the Nile perch	Wilson (2002)
1991–2000	Concerned about reduction in catches (from 45 tonnes to 15 tonnes per boat) and long fishing trips			Witte and Densen (1995) and Mkumbo et al. (2002)
2000 -	Fisheries management is legitimate Worried about corruption	Worried about the pressure on fish resources (the increase in the number of fishermen from 11,923 in 1955 to 76,765 in 2004; the increase in the number of fishing gears, especially hooks, from 296,500 in 1968 to 3,040,773 in 2004, among others)	Worried about dwindling incomes generated from fishing	Wilson (2002)

(continued)

Table 8.12 (continued)

	Indicator (Perception on the state of the fisheries)	Source		
		Fishermen	Researchers	Government officials
2005 onwards	Fishing as a way of life	Mixture of fishing as a way of life and economic activity	Worried about declining stocks and illegal gears	Onyango (2011)
				SOFRECO (2013)

Table 8.13 Issues on which fishermen and managers had differing opinions

Year	Issue of disagreement	Source
2000	There will be no catches if a fisherman does not use a small mesh-size gear.	SEDAWOG (2000)
	No more fishermen should be allowed to fish from the lake.	Heck et al. (2004)
	Conflicts on issues relating to cross-border fishing and fish trade.	

Table 8.14 Areas fishermen and managers have common opinions

Year	Issue of agreement	Source
2000	Fewer fish now than 5 years before.	SEDAWOG (2000)
	Longer fishing trips 5 years before.	
	Less fish diversity than 5 years before.	
	More boats than 5 years before.	
	Fish sizes are smaller than 5 years before.	
	Fishing is less beneficial than 5 years before.	
	Stakeholders especially the local communities should be involved in the management of the fisheries.	

contribution; FI = Fishery income), has grown from 0.4% in 1993 (data permitting) to 1.8% in 1998. However, according to a report by the Ministry of Planning and Economic Development, the overall fisheries contribution to the economy has remained stable since 1996–2011 (URT 2006). Over 60% of this contribution is from the lake. On average, the fisheries have been contributing between 1.5 and 2.5% to the GDP and the lake's contribution is on average 1.5% (Fig. 8.6). Kulindwa's estimation for the period between 1968 and 1998 indicates that fisheries contribution to the economy grew and stabilized sometime from 2000 to 2003. However, with the observed declining catch per unit effort (CPUE) of most species from the lake, the lake's contribution to the GDP changed course. It has been and continues to be in decline.

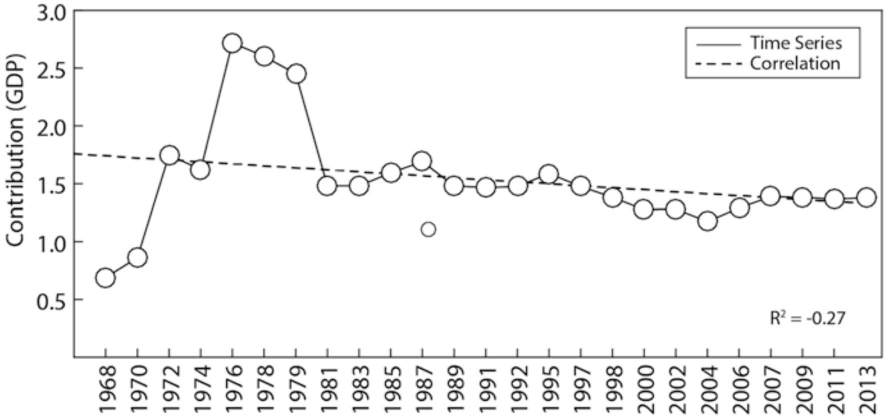

Fig. 8.6 Contribution of Fisheries and Lake Victoria Fisheries, Tanzania to the GDP

8.3.13 Incomes

Incomes from the lake's fisheries at the national level have averaged at about USD 100 million annually. It has been generating about the same amount in foreign exchange earnings. Nile perch fishers have been earning on average US$ 400 million annually, tilapia fishers earning USD 100 million while dagaa fishers have been earning US$ 194 million. Boat owners have had the greatest share of the fisheries earnings between them and the crew. Their share constitutes on average, 70% of the total incomes that the fisheries generate.

8.4 Conclusions

Lake Victoria is an important socio-economic resource for the riparian states and communities. The observed increases in the number of fishermen, gear, fish traders and processors as well as trading and processing systems reflect the fact that the fisheries are operating both at subsistence and commercial levels. The fisheries of Lake Victoria now operate under a different socio-cultural environment from that of the past. It is, however, not very clear whether the new socio-cultural set-up is embedded within the cultural set-up of the riparian communities. The fisheries in question are largely artisanal as industrial and trawl fishing have been banned.

The collection and keeping of data on employment, fish trade and fish processing and prices is highly underdeveloped or very poor. The data that have been gathered so far lack information on the socio-economic characteristics of the riverine fisheries, the cooperative societies, and the satellite lakes.

8.5 Recommendations

- Efforts to understand the environment in which the fisheries operate should be prioritised. The riparian communities' differences and potential synergies need to be considered when dealing with these communities. An understanding of the environment will enable planners to direct resources obtained from the fisheries to the improvement of the welfare of the riparian communities.
- Changes occurring across the world are greatly impacting upon the riparian communities. The changes demand a quantitative approach to the analysis of qualitative issues, except for the social issues relating to the riparian communities and others. For this reason, it is important to explore how power, socio-cultural capital and taboos can be used to address the concerns of the riparian communities.
- Given the changes that have taken place in Lake Victoria fisheries since the introduction of the Nile perch and the corresponding changes in the fish stocks, it is important to gather data on the riverine fisheries, the cooperatives, the satellite lakes and the demand for fish. If this is done, the management of the lake will be effective.
- The state of the lake's resources demands the participation of local communities in the management of the lake. To this end, the already formulated BMUs should be closely monitored and improved so that they may manage the lake effectively.

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Chapter 9
Historical Trends in Fisheries Management

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Abstract The management of the fisheries of Lake Victoria has had several successes and failures. These failures were either due to inadequate awareness of the fishing communities on the proposed protocols, and/or little attention paid by the government during the colonial period on the importance of lake fisheries. After independence of the riparian states, each country developed her own approach, but based on the findings of research and recommendations from Lake Victoria Fisheries Organization (LVFO). Lately, through the LVFO and especially under the Lake Victroria Environmental Management Project (LVEMP), more concrete and harmonised fisheries management programmes have been developed. In Tanzania, the evolution of the management of fisheries can be divided into four major historical periods: The pre-colonial period, the colonial period, the state-owned economy period (1961–1985) and the liberalised economy period (after 1986). This chapter summarises all the events that took place during these four major periods. It also discusses the results and proposes the way forward. In particular, the chapter emphasises the threats to the lake fisheries resources and other aquatic living organisms arising from effluent discharges from towns and the agricultural areas surrounding the lake. The different effective management organs such as BMUs (developed under LVEMP I and incorporated into Fisheries Act of 2003) have been mentioned as the products of LVEMP I. Finally, the chapter makes three recommendations related to future management of the lake.

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9.1 Introduction

The management of the fisheries of Lake Victoria has had several successes and failures. The failures can be attributed to the inability of members of fisheries staff to manage the fisheries well due to lack of knowledge on which to base management plans or due to the stakeholders' illiteracy and the former colonial rulers' negative attitudes towards the management of the fisheries of the lake. For example, during the colonial era (1950–1953) the colonial government had a variety of conflicting laws and regulations on the fisheries for the three riparian colonies of Kenya, Tanganyika and Uganda (Lake Victoria Fisheries Service 1953).

Whereas Kenya and Uganda had Fish and Crocodile Laws for regulating and managing the fisheries, Tanganyika had a Fisheries Ordinance and a Trout Protection Ordinance (Tanganyika Territory 1950) for controlling the fisheries. The colonial rulers considered fish as a native food of little economic value, a view that led to management of the fisheries receiving little government attention.

Attempts to manage the lake were made for the first time in 1927, when the first survey was conducted by Graham (1929). At that time, it was noted that gillnets were negatively affecting the stocks, a situation which necessitated setting of a minimum mesh size of 5 inches in 1933. However, gillnets were first introduced to the Tanganyika waters of Lake Victoria in 1908 in Mwanza (Fisheries Division 1966). When these nets were introduced to Lake Victoria, people fished the lake for mainly subsistence purposes and only a small percentage of the fish caught was sold. However, as the demand for fish increased, more fish were harvested, which resulted in overfishing.

It is argued that by 1953, the introduced seine nets (long drag-nets) had contributed to the decrease in catches. It was reported that the control of prices, especially in Kenya and Tanganyika, reduced the amount of fish sold in Mwanza and Kisumu. In Uganda, however, the price for tilapia was not controlled, hence the increase in sales.

Prior to 1953, the Kenyan rules governing the management of Lake Victoria had not been harmonized with those of Tanganyika and Uganda. This led to the use of 2½ inches mesh size gillnets. These nets were said to be harmless to the tilapia stocks, additionally the nets were used to catch other kinds of fish, which were either predators or competitors to the tilapias. As such, seine nets were used in the lake until the decision to reduce their number was made. In Tanganyika, the licensing of the nets was hampered by a lack of ground support, particularly vessels and a small number of workers. As a result, most fishermen fished without fishing licences.

In Uganda, the use of 4-inch nets was illegal. The use of mosquito nets started before 1955. The implementation of the ban on the use of illegal nets was difficult in Uganda since at the time nets were made of synthetic fibres and so could be left in the water for a long time and be removed when fish had been caught. In addition, the colonial government established the Lake Victoria Fisheries Board, which was mandated to make recommendations for the management of the fish resources of Lake Victoria. For example, in 1956, the Board had a meeting to review the mesh sizes of gillnets in the lake (Lake Victoria Fisheries Service 1953 and 1955/1956).

It has been noted that the fishermen in the Tanganyika waters were licenced by the local authorities because of the small number of workers. As a result, a large number of fishermen operated without licences as a result it caused discontent among those who were licenced.

The development of fisheries in Mainland Tanzania commenced in 1965, when the Fisheries Division was established under the Ministry of Agriculture, Food and Cooperatives. A director was appointed and an administrative structure to administer the fisheries and to implement the development plans was created. Training was the major activity, which was carried out by the Fisheries Division. In Mwanza, the regional Fisheries Officer was responsible for training as of 1960/61. By the middle of 1965, there were 24 pre-service students, 20 trainees from the Tanganyika African National Union (TANU) Youth Fishing Unit, 14 fishermen and 12 student boat builders. The training was conducted in Mwanza at Nyegezi Training Institute. However, there were no training facilities, equipment and teachers at Nyegezi, apart from boarding and lodging services. The Nyegezi Training Institute became the nucleus of the Ministry of Agriculture, Food and Cooperatives and training started in 1960/61. At the end of 1965, the number of trainees had grown to 41 pre-service students, 15 National Service men, 24 fishermen and 12 student boat builders.

Furthermore, plans were made to establish a certificate in fisheries training centre for staff in the field and fishermen at Mbegani, Bagamoyo and a diploma in fisheries training institute for field officers at Kunduchi, Dar es Salaam. Mbegani Training Centre and Kunduchi Training Institute became operational in 1966. Graduates from Mbegani and Kunduchi were posted to Lake Victoria regions to provide extension services to fishermen and fish processors.

The management of fishery resources in Tanzania can be divided into four historical periods, starting with the pre-colonial period, when the fishery resources were managed by traditional rules. During that period, the destruction of the resources was minimal because the demand for fish and fish products was low owing to a small population, poor processing, handling and preservation methods and poor transportation networks. This period was followed by the colonial period when certain regulations were formulated for use in the Great Lakes region and in the rivers with exotic fish species like the trout. In general, fishing was characterized by the use of poor traditional fishing methods, very few motorized fishing vessels and poor fishing, processing, handling and preservation methods. This period was followed by two post-independence periods: the state-owned economy period (1961–1985) and the liberalised economy period (after 1986).

Due to the decline in stocks, all the riparian states have introduced a fisheries Monitoring, Control and Surveillance (MCS) programme. Currently, the programme is geared towards educating stakeholders on the effects of destructive fishing gears and methods and on the destruction of such gears. In addition, the riparian states have established the Collaborative Fisheries Management (CFM) Programme since the end of 1990s and early 2000s in order to curb illegal, unreported and unregulated (IUU) fishing activities in the lake. Despite the intensity of the programme including the burning of illegal nets, there is still rampant illegal fishing in the lake. This has resulted into the decline in the fish stocks, particularly the Nile perch.

In addition, the stock assessment project carried out by the European Union (EU)–Lake Victoria Fisheries Research Project (LVFRP)–also revealed that the stocks were declining. It is acknowledged worldwide that different scientists develop and use different tools for assessing different stocks. The data gathered by the LVFRP (2001) showed an alarming deterioration of the sex ratio of the Nile perch, that is, there were only a handful of mature female Nile perch. If this is the case, then the female Nile perch in the lake are in grave danger. To save them, the LVFRP recommended a project to institute a slot size of 50–85 cm TL for the Nile perch so that large females can be given chance to spawn. The riparian states have been enforcing the slot size for the Nile perch since the year 2000.

9.2 Results

The evolution of the management of fisheries during the colonial era (pre-1961), post-independence period (state controlled economy, 1961–1986) and the liberalised economy period (post-1986) is described in Table 9.1.

9.3 Discussion

The riparian communities of Lake Victoria, the partner states and the international community benefit in one way or another from the fishery resources of the lake. However, there are environmental threats, which include rapid deterioration of the quality of water due to increased nutrients and discharges of effluents from the towns and industries around the lake. The infestation of the lake by water hyacinth, increased nutrient enrichment, discharges of effluents and increased algal growth is causing de-oxygenation and threatening artisanal fisheries and biodiversity, thus leading to disappearance of indigenous fish species and destruction of the wetlands, among others (Government of Kenya, GoK/Government of Uganda, GoU/Government of Tanzania, GoT 1996). All these have lead to loss of biodiversity and short and long-term socio-economic benefits for the people and the country as a whole. During the life of LVEMP I, positive efforts were made to reduce the amount of water hyacinth infestation in the lake. Those positive efforts are still being implemented although the weed has resurfaced in some spots in the lake. The reinforcement of the weevil rearing station has been done and are operationalized by the BMUs to sustain the activity. Fisheries Education and Training Agency (FETA) Nyegezi Campus staff have been trained and are also handling one weevil rearing station. This will enable the institution to train their students as well as the BMUs for purposes of building sustainability. The fishermen and the communities living along the lake also do manual removal of the water hyacinth.

Table 9.1 Evolution of Lake Victoria fisheries management during the colonial and post-independence periods

	Status		
	Colonial period	Post-independence period	
		1961–1985	1986–2005
Issue/Activity	Before 1961	(State owned economy)	(Liberalized economy)
Extension service			
Training of national Fisheries Staff in extension and management skills	There were no national Fisheries training institutes	Training was provided by Nyegezi, Mbegani and Kunduchi Fisheries Training Institutes and higher and medium training institutes inside and outside the country	Training has been provided by Nyegezi, Mbegani (FETA) and Kunduchi Fisheries Training Institutes and higher and medium training institutes inside and outside the country
Training of fishermen in long lining, trawling, gillnetting, engine repair and maintenance and gear repair	Nil	Done at Nyegezi Freshwater Fisheries Training Institute (NFFTI) and Fisheries extension staff	Nil
Training of fishermen in lift net fishery and live bait fishery	Nil	Nil	Training has been conducted by Fisheries extension staff in collaboration with experienced fishermen
Training of fishermen, processors and traders in improved fishing methods and improved fish handling and processing methods	Extension services were provided by colonial staff	Training was provided by national trained fisheries staff	Training was provided by national trained fisheries staff
Training of fish inspectors, managers and workers in fish processing plants, Beach Management Units (BMUs) in fish quality control and safety assurance aspects	Nil	Nil	Training provided by the Government, Higher learning institutions (public and private)
Training on Fisheries Policy of 1997	Nil	Nil	Training provided to Fisheries Training Institutions and extension staff

(continued)

Table 9.1 (continued)

	Status		
	Colonial period	Post-independence period	
		1961–1985	1986–2005
Issue/Activity	Before 1961	(State owned economy)	(Liberalized economy)
Fisheries policy and fisheries legislation			
The National Fisheries Policy was in place	Nil	Nil	The National Fisheries Sector Policy and Strategy Statement was put in place and was approved by the Government in 1997. Its overall goal is to promote conservation, development and sustainable management of the fishery resources for the benefit of the present and future generations. Fisheries Development Division became the Competent Authority on issues related to fish quality control and safety assurance.
The National Fisheries Policies of the riparian states were harmonized	Nil	Nil	Nil
The National Fisheries Legislation was in place	Trout Protection Ordinance Cap. 160 which was enacted in 1929 provided for the protection of species in highland streams for sport fishing and did not cover Lake Victoria	Fisheries Act No. 6 of 1970 provided for the Minister to make regulations for the protection, conservation and wise use of natural resources. Regulations relevant to Lake Victoria included	GN. 276 of 1.9.1989 prohibits the possessing and using of poison to kill fish.
		GN 5 of 21.1.1982 prohibits fishing in closed fishing areas	GN. 369 of 10.3.1994 prohibits the use of beach seine nets, dagaa nets <10 mm and gillnets < 5”
			GN. 370 of 7.10.1994 prohibits the use of trawl nets
			GN. 189 of 6.6.1997 Amendment of fines from Tsh 20,000 to 100,000
			GN. 624 of 9.10.1998 Amendment of fines to not less than Tsh 300,000.

	Fisheries Ordinance No. 36, which was enacted in 1950 provided for the establishment of boards for specified water bodies. The boards were empowered to make their own regulations and did not cover Lake Victoria. Regulations to control fish nets in Lake Victoria became effective in 1951.	GN. 5 of 21.1.1982 prohibits fishing in closed fishing areas.	GN. 193 of 1.8.2003 prohibits the fishing and sale of the Nile perch <50 cm and >85 cm total length (slot size)
		Local Government (District Authorities) Act No. 7 of 1982 Section 169. Local Government (Urban Authorities) Act No.8 of 1982 Section 71 provided for Local Government to manage fishery resources in their jurisdictions.	GN. 300 of 8.9.2000 Fish Quality Control and Standards Regulations 2000, Fisheries Act No. 22 of 2003 provides for policy formulation and implementation of the Act for sustainable conservation, development and management of the fishery resources.
Registration and licensing of fishing vessels and licensing of fishermen	Done under Colonial Regulations	Done under Fisheries Act No. 6 of 1970	Done under Fisheries Act No. 6 of 1970 and Fisheries Act No. 22 of 2003 and Fisheries Regulations, 2009
The National Surveillance Unit was in place	Nil	Nil	Established under Fisheries Act No. 22 of 2003
The National Fisheries Development Fund was in place	Nil	Nil	Established under Fisheries Act No. 22 of 2003 and Fisheries Regulations, 2005
Co-management had already begun	Nil	Nil	Incorporated in Fisheries Act No. 22 of 2003 and Fisheries Regulations, 2005
The Fish Levy Trust Fund for Lake Victoria was in place	Nil	Nil	The National Fisheries Development Fund was established under Fisheries Act No.22 of 2003 and Fisheries Regulations, 2005
			Establishment of the Fish Levy Trust Fund for Lake Victoria is at different stages of implementation (Regionally, Harmonized Study report was in place and Tanzania had a Business plan).

(continued)

Table 9.1 (continued)

	Status		
	Colonial period	Post-independence period	
		1961–1985	1986–2005
Issue/Activity	Before 1961	(State owned economy)	(Liberalized economy)
National Fisheries Legislations were harmonized	Nil	Nil	Areas of harmonization have been identified and Tanzania has incorporated those areas in Fisheries Act No. 22 of 2003 and Fisheries Regulations, 2005. However, these Regulations were revoked and replaced by the Fisheries Regulations, 2009 which are currently, effective.
Lake Victoria Convention was in place	Lake Victoria Fisheries Service	Nil	The Convention was signed in 1994 by the riparian states. Article XVIII of the Convention provides for the Organization to perform any legal acts that are necessary for of the discharge of its functions.
Fish quality control and safety assurance			
Traditional and improved fish handling and processing methods	Traditional smoking, smoke kilns, salting and sun drying	Traditional smoking, smoke kilns/ or Chorkor kilns, salting, sun drying and an experimental processing plant was established at NFFTI.	Traditional smoking, Chorkor kilns, salting, sun drying, chilling, freezing and introduction of insulated containers for holding fish
Industrial fish processing	Nil	One plant was established in Mwanza to process Haplochromis.	11 Nile perch processing plants have been established in the Lake Zone regions, and by 2005 eight plants were operational.
Fish export market			
fFish export market within East Africa	Smoked and salted fish of indigenous fish species were exported to Kenya and Uganda.	Smoked, salted and sun-dried fish indigenous and exotic fish species were exported to Kenya and Uganda.	Smoked, salted and sun-dried fish indigenous and exotic fish species were exported to Kenya and Uganda.

Fish export market outside East Africa (Smoked and salted Nile perch and Rastrineobola argentea)	No smoked and salted fish of indigenous fish species were exported outside East Africa or Tanzania.	Smoked, sun dried and salted fish of exotic and indigenous fish species were exported to Burundi, Rwanda and Zaire.	Smoked, sun dried and salted fish of exotic and indigenous fish species were exported to Burundi, Rwanda, Zambia, Malawi and Zaire.
Fish export of fresh, chilled and frozen Nile perch and its products	Nil	Fresh Nile perch were exported to Kenya.	Chilled and frozen products of Nile perch were exported to Europe, Asia, Australia, Middle East, the USA, etc.
Aquaculture			
Training to the fisheries' extension officers (long and short courses) and to farmers	Nil	Training was provided by NFFTI and the fisheries' extension staff.	Training was provided by NFFTI and Mbegani Fisheries Development Centre, Higher and medium learning institutions inside and outside the country and fisheries extension staff institutions.
Establishment of fingerlings breeding ponds	Nil	NFFTI, Malya and Rwamishenye fish breeding ponds were established.	Nyegezi (TAFIRI), NFFTI and several farmers provided fingerlings to farmers.
Aquaculture development strategic plan was in place	Nil	Nil	A draft National Aquaculture Developmemnt Strategic Plan (NADSP) was prepared and was planned to be completed by the end of November 2005. However, it was completed in 2009.
Fisheries collaborative management (co-management)			
Co-management was introduced for major and minor waters	Nil	Nil	511 Beach Management Units (BMUs) were established between 1998 and 2000 in Kagera, Mara and Mwanza regions. They were reformed in 2005 and remained 433 BMUs
Individual and joint patrols between the BMUs and the fisheries staff had already begun	Nil	Nil	Both individual and joint patrols were being conducted.

(continued)

Table 9.1 (continued)

	Status		
	Colonial period	Post-independence period	
		1961–1985	1986–2005
Issue/Activity	Before 1961	(State owned economy)	(Liberalized economy)
The BMUs participated in the maintenance of beach hygiene and sanitation and the management of floating barges and the beach environment management in general	Nil	Nil	Beach hygiene and sanitation in 575 (2004 Lake Victoria Frame Survey) beaches were being maintained by the BMUs and ten constructed floating barges were being managed by the BMUs.
The National BMUs Guideline/ operational manual was in place	Nil	Nil	The Harmonized BMU Guideline was domesticated to National BMU Guideline printed and distributed to the Lake Zone regions and the riparian states. Distribution of copies of the manual to other regions in Tanzania was ongoing and translation of the manual into Kiswahili was completed by the end of 2005.
National guidelines for establishing the BMUs were in place	Nil	Nil	The guidelines (English and Kiswahili Languages) were finalized and e printed and distributed by the end of November 2005.
Fisheries association			
Fishermen's association was in place	Nil	Fishermen's associations/ cooperatives were formed in Kagera, Mara and Mwanza regions.	Most of the associations/co-operatives died a natural death. However, fish traders established their own associations/co-operatives.
BMU Savings and Credit Co-operatives Societies (SACCOS) were in place	Nil	Nil	The BMUs established sources of finances which include SACCOS in Kagera, Mara and Mwanza regions and the SACCOS were at different stages of registration.

Research and development			
Biological, limnological, stock assessment, and socio-economic studies	Done by the East African Freshwater Fisheries Research Organization (EAFFRO) and private institutions and individuals.	Carried out by the EAFFRO and International Organizations and private institutions and individuals.	Carried out by TAFIRI, the Fisheries Development Division, higher learning, private and public, institutions and International Organizations inside and outside the country.
The Lake Victoria Fisheries Organization (LVFO) was in place.	Nil	Nil	Established by a convention signed by the three countries in 1994.
Regional and national projects			
Haplochromis Ecological Survey Team (HEST) funded by the Government of Netherlands	Nil	Conducted taxonomy, limnological and ecological studies on Haplochromis, the Nile perch and Rastrineobola argentea in the main lake.	Conducted taxonomy, ecological studies and limnological studies on Haplochromis, the Nile perch and Rastrineobola argentea.
Inland Fisheries Planning, Development and Management in Eastern/Central/Southern Africa (IFIP) – FAO and UNDP-funded project	Nil	Nil	Conducted socio-economic studies.
Lake Victoria Fisheries Research Project (LVFRP) – EU-funded project phase 1	Nil	Nil	Long and short courses were provided to TAFIRI staff.
			Procured research equipment.
Lake Victoria Fisheries Research Project (LVFRP) EU-funded project phase 2	Nil	Nil	Conducted fish stock assessment on the Nile perch and Rastrineobola argentea, limnological and socio-economic studies in the main lake.

(continued)

Table 9.1 (continued)

	Status		
	Colonial period	Post-independence period	
		1961–1985	1986–2005
Issue/Activity	Before 1961	(State owned economy)	(Liberalized economy)
Lake Victoria Environmental Management Project (LVEMP) World Bank- and GEF-funded project	Nil	Nil	Field and research equipment was procured and training (long and short courses) was provided to the project's staff.
			Management interventions were executed by the Government implementing institutions.
			Biological, ecological, limnological and biodiversity studies were done on both the main lake and rocky habitats and satellite lakes.
			Socio-economic, aquaculture and information and data base studies were conducted.
The International Union for Conservation of Nature's (IUCN) project	Nil	Nil	Socio-economic studies and training to the BMUs were conducted. See above change to be 1986–2016
Implementation of the Fisheries Management Plan (IFMP) project	Nil	Nil	Field and research equipment would be procured.
			Management interventions were at different stages of implementation.
			Stock assessment, trawl, hydro–acoustic, gillnets, experimental fishing, catch assessment surveys, biological and environmental data collection were at different stages of implementation.
			Capacity building was at different stages of implementation.

Lake Victoria Environmental Management Project II (LVEMP II) World Bank- and GEF-funded project (2009–2017)	Nil	Nil	Implementation of the research findings of LVEMP I.
			Institutional capacities were strengthened.
			Field and research equipment for Fisheries Development Division were procured (e.g., vehicles, patrol boats, chemical laboratory facilities, data base equipment) and training (long and short courses) was provided to the project staff and Local Government Authorities.
			Management interventions were executed by the Government implementing institutions.
			Biological, ecological, limnological and biodiversity studies were done on both the main lake rocky habitat and satellite lakes (e.g., Frame surveys, Catch assessment surveys and Hydroacoustic surveys).
			Socio-economic, aquaculture and information and data base studies were conducted.

9.3.1 Extension Services

The major barriers to the development of the fisheries sector include inadequate capital, education and poverty (Fisheries Division 1968). Before independence, there were no national fisheries training institutes. Since the establishment of the Fisheries Development Division in 1965, training has been provided both inside and outside the country. Fisheries staffs have continued to advise on and train fishermen in the establishment of fisheries associations, adoption of improved fishing technology, fish preservation, processing and handling methods, aquaculture development and beach sanitation and hygiene.

9.3.2 Fisheries Policy and Fisheries Legislation

The Fisheries Policy provides guidelines for fisheries conservation, protection, development and management. Before independence, there were no national fisheries policies. Although the Fisheries Development Division was officially established in 1965 under the Ministry of Agriculture, Food and Co-operatives, the First National Fisheries Sector Policy and Strategy Statement was launched by the Government in 1997 and reviewed in 2015. The overall goal of the National Policy is to promote conservation, development and sustainable management of the fishery resources for the benefit of present and future generations. The Fisheries Policy 2015 and legislation (Fisheries Act 2003) operate within the macroeconomic framework of the country such as the Tanzania Development Vision 2025 and the Second National Strategy for Growth and Reduction of Poverty (NSGRP II) and the United Nations Sustainable Development Goals, particularly Goal 14 (SDG 14). The overall goal is to contribute to national poverty reduction through sustainable management and utilization of the fisheries resources.

The Trout Protection Ordinance was enacted in 1929 (Tanganyika Territory 1929) with the aim of protecting trout in 24 streams in the then colony (Trout Protection Ordinance 1929). However, it was realized that the Trout Protection Ordinance had certain defects, and so the Colonial Government enacted the Fisheries Ordinance in 1950 (Fisheries Ordinance 1950). The second ordinance dealt primarily with Marketing Boards and had nothing to do with the management of Lake Victoria. The fisheries of Tanganyika continued to operate under colonial laws until 1970 when a new Fisheries Act was enacted. A number of regulations were included in the Fisheries Act of 1970 and fisheries regulations (the Principal Regulations 1973) were developed to ensure the smooth implementation of the Act (see Table 9.1).

The Fisheries Act No. 6 of 1970 mandated the Minister responsible for fisheries to manage, protect and develop the fishery resources (Fisheries Act 1970). Since the Act was enacted during the one-party system, a number of issues were related to the National Policy on Socialism and Self-reliance. The passing of the Fisheries National Policy in 1997 by the Government and the transformation of the national economy from a state-owned economy to a liberalized economy forced the Fisheries Division to repeal and replace the Fisheries Act No. 6 of 1970 with a new Fisheries Act No. 22 of 2003. This law mandates the Minister as the person responsible for the formulation of policies and the implementation of the law for sustainable conservation, development and management of fishery resources (United Republic of Tanzania 2004).

The management of the fishery resources of Lake Victoria requires joint management and common strategies through harmonized national fisheries policies and laws. The partner states have initiated a process of harmonizing their national fisheries laws, an initiative which is currently at different stages of implementation. The three countries have signed a convention for the establishment of a Lake Victoria Fisheries Organization (LVFO), which became operational in 1996. The objective of the Organization "shall be to foster cooperation among contracting Parties, harmonize national measures for sustainable utilization of the living resources of the lake and develop and adopt conservation and management measures" (LVFO 2001).

9.3.3 Fish Quality Control and Safety Assurance

Fish deteriorate rapidly and therefore it is essential to preserve fish immediately after capture so that they can be processed and transported to distant domestic markets or consumed later. Fish smoking was one of the traditional fish processing methods. However, the product, which came from traditional method, were of poor quality and did not last long. Smoking kilns were introduced in the 1950s to improve the traditional methods (Lake Victoria Fisheries Services 1953). Modern smoking kiln was introduced at TAFIRI Mwanza. The processors however, did not adopt this technology, because it was expensive to construct despite its energy saving capability.

After independence, fisheries extension services were strengthened and more improved fish handling and processing methods such as salting, chorkor kilns, freezing and chilling were introduced. Important processing methods include fish smoking using chorkor kilns and salting for both Nile tilapia and Nile perch, sun drying for *Rastrineobola argentea* (dagaa) and icing for Nile perch and Nile tilapia. In addition, modern preservation methods are used to keep fillets in the processing plants. These include chilling and freezing products for the domestic and export markets.

9.3.4 Fish for Export Market

In 1965, it was reported that the Tanzanian part of Lake Victoria contained the most important commercial fisheries in East Africa. In addition to supplying fish to local markets, Tanzania exported fish to Kenya and Uganda. In 1968, the export of processed fish from the West Lake Region to Uganda went down, but exports to both Kenya and Uganda from Ukerewe Island (Fisheries Division 1968) were good. It was observed that there was a high demand for fish in the two neighbouring countries, which could be supplied by Mainland Tanzania. However, it was reported that poor roads, communication and distribution facilities hindered the distribution of fish to the different markets. In addition, lack of capital often limited the people's capacity to buy considerable amounts of fish.

Fish and fishery products from Lake Victoria took on a new trend in the mid-1980s, during the Nile perch boom. The export of fresh, smoked, salted Nile perch and dried Rastrineobola argentea to Burundi, Uganda, Rwanda, Democratic Republic of Congo (DRC), Sudan and Kenya increased the income of fishermen and fishmongers, as well as the national income. In early 1992, Nile perch processing plants were established in the Lake Zone such that fish production (particularly the Nile perch), increased and Nile perch fillets and other products found a market in Europe, the Far East, the Middle East and USA, among others. The major importers of Nile perch fillets from Lake Victoria include several EU countries and in 2004 the total export was 42,354 tonnes, which were valued at US$ 100.1 million, while the total royalty to the Fisheries Division was US$ 6.4 million (Fisheries Division 2004).

9.3.5 Aquaculture

During the colonial era, insufficient efforts were made to promote aquaculture in the Lake Victoria Basin. After independence, farmers were trained on aquaculture development and two fish breeding ponds namely Malya and Rwamishenye were established. By the end of 1968, there were 705 stocked fishponds in the Western Lake Region (Fisheries Division 1968). However, from the 1970s to the early 1990s fish farming activities were undertaken at a lower scale. In 1997, fish farming was promoted again, reaching its peak by mid 2005 when there were a total of 404 fishponds in the Lake Victoria Zone. The major problems relating to fish farming have been the absence of strategic plans for aquaculture development, inadequate supply of quality fingerlings, and inadequate supply of water in some parts, poor feeding and cropping and stunted growth. These drawbacks are currently being addressed, including possibility of cage farming in the lake.

9.3.6 Collaborative Management of the Fisheries

There is a weakness in the enforcement of the existing laws and regulations in the fishing industry, particularly now when there is a growing demand for fish in both domestic and external markets. Overfishing, the use of illegal fishing gear (beach seines, mosquito nets, under meshed gillnets, etc.) and other illegal fishing practices are rampant particularly in fish breeding areas, fishing grounds and estuaries. These practices threaten the fishing industry and are contrary to the objectives of Fisheries

Act No. 22 of 2003, that is, protection, conservation, development and wise use of fishery resources (United Republic of Tanzania 2004).

Co-management of the fisheries as an alternative to centralized command and control of fisheries management is often said to be a solution to the problems of resource use conflicts and overexploitation. In 1997, the Government realized that it could manage fishery resources more effectively in partnership with stakeholders (Fisheries Development Division 1997). Collaborative Fisheries Management (CFM) was introduced for the first time in the Mwanza Gulf in 1998 by the establishment in every landing site of a Beach Management Unit (BMU). More than 511 BMUs had been formed in all the twelve riparian districts by July 2000 (LVEMP 2000). The development in terms of the number of functioning BMUs is an indicator of the level of the participation of the community in the management of Lake Victoria fisheries.

Since co-management began, the Beach Management Units have been collaborating with fisheries staff to curb illegal fishing practices, to participate in data collection for Catch Assessment Surveys and Frame Surveys, in ensuring beach hygiene and sanitation and in environmental conservation activities, among others. The Fisheries Act, 2003 under Section 18 has incorporated co-management whereby members of the BMUs have been empowered to enforce the Fisheries Act, 2003 for sustainable management and development of fishery resources (United Republic of Tanzania 2004).

9.3.7 Fisheries Associations

Attempts to enable fishermen form fisheries organizations/associations started in the mid-1960s. It was found that most individual fishermen worked in remote areas and were not organized. As a result, they were in an unfavourable situation for a long time. Although fishermen were making reasonable incomes, individually, they had no bargaining power and fishmongers usually exploited them. Attempts were made to foster co-operation among the fishers and in fact, one association was officially registered in 1968. In addition, there were several unregistered associations, but all had common problems such as lack of capital, poor leadership and lack of competent and honest managers to run them efficiently (Fisheries Division 1968).

Consequently, most of the associations died a natural death. Fortunately, since the inception of the Lake Victoria Environmental Management Project, attempts have been made to sensitize the fishing communities through the members of Beach Management Units to establish Savings and Credit Cooperative Societies (SACCOS). The aim is to establish formal fisheries associations from the grassroots level to the national level, which will provide a platform for fishermen to air their grievances relating to fish prices and other related issues. These initiatives have started to bear fruits and today there are a number of registered SACCOS such as Kayenze (Ilemela District), Burugu, Kiemba and Suguti (Musoma Rural District), Chole, Kigongo Ferry and Mwasonge (Misungwi District). It is observed that the fishers, who are mainly artisanal, should formalize their associations so that they may have strong voice in bargaining for fish prices, borrowing funds from financial institutions.

9.3.8 Research and Development

Up until 1977, freshwater fisheries research was under the East African Freshwater Fisheries Research Organization (EAFFRO) whose headquarters were in Jinja, Uganda. The studies carried out by EAFFRO were on limnology, stock assessment and socio-economics.

Despite the collapse of the East African Community (EAC) in 1977, research on the fisheries of the three East African states continued but was now carried out separately by the individual countries. In Kenya, fisheries research was carried out by the Kenya Marine and Fisheries Research Institute (KMFRI) whereas in Uganda, it was carried out by the Ugandan Fisheries Resources Research Institute (FIRRI). In Tanzania, fisheries research activities were handed over to the Tanzania Fisheries Research Institute (TAFIRI), which was instituted in 1980 by an Act of Parliament (No. 6).

Fisheries management issues of Lake Victoria were handed over to the Food and Agriculture Organization of the United Nations (FAO) under the CIFA–Sub-committee for Lake Victoria (from 1977 to 1994) when the Lake Victoria Fisheries Organization (LVFO) was formed. A convention was signed in 1994 by Kenya, Tanzania and Uganda.

9.3.9 Regional and National Projects

Despite the work done by EAFFRO, existing records do not show whether prior to independence, there were fisheries research and management projects geared towards developing fisheries management activities in the Tanzanian part of Lake Victoria. The first project on Lake Victoria was implemented by the Haplochromis Ecological Survey Team (HEST), which was funded by the Government of the Netherlands from the mid-1970s to the early 1990s. The project conducted research on the taxonomy, limnology and ecology of haplochromines and the dagaa (*R. argentea)*. Another project was the Inland Fisheries Planning and Development in Eastern/Central/Southern Africa (IFIP), which undertook socio-economic studies. This project was followed by the Lake Victoria Fisheries Research Project (LVFRP), which was funded by the European Union. The project was concerned with capacity building in terms of training and equipment, limnology, stock assessment of *Lates niloticus* and *R. argentea,* including socio-economic studies. The project developed a fisheries management plan for Lake Victoria.

The Lake Victoria Environmental Management Project (LVEMP) was established by a tripartite agreement signed by the three countries in 1995. The project was undertaken between July 1997 and 31st December 2005. The project carried out fisheries research and management activities, for example, undertaking biological, biodiversity, ecological, aquacultural, socio-economic and information and database studies. Fisheries management interventions included surveillance, co-management, aquaculture development, frame surveys, fish quality control, the curbing of fish post-harvest losses and the undertaking of fish levy trust studies, among others.

The Implementation of Fisheries Management Plan (IFMP) project was a five-year (2000–2008) regional project funded by the EU. However, it was extended up to 2010. It was expected that it would support fisheries research and management activities (see Table 9.1). All these projects generated useful information for the development of Lake Victoria fisheries resources for the benefit of all the three riparian countries.

9.4 Conclusion

The development of fisheries in Tanzania can be divided into three major periods, namely the colonial period, the post-independence period and the period of liberalized economy. The colonial period was characterized by a slow growth in the sector because of the absence of a national fisheries policy and a lack of fisheries training institutes. Fisheries regulations were introduced in 1951, but before then, fishery resources were managed through traditional rules. The processed fish products were of low quality because the processing involved poor smoking (using different firewoods), salting (using unspecified amount of salt per kg of fish), and sun drying (depending on the amount of solar energy at the time of drying).

The post-independence period was characterized by new developments in the fisheries sector, for example, the establishment of three national fisheries training institutes. Many fisheries staff were recruited and fisheries extension services for engine maintenance, fishing gear making and mending, aquaculture, fish handling, processing, preservation, marketing, data collection, among others, were provided. There were no fisheries policies at that time. The Fisheries Act of 1970 together with Fisheries Regulations were enacted and enforced.

The period of liberalized economy was characterized by the passing of the first National Fisheries Policy and Strategy Statement. The Fisheries Act of 2003 replaced the Fisheries Act of 1970, with the aim being to come up with a Fisheries Act that would adequately cope with the developments in the National Policy on Privatization. The incorporation of co-management and the Fisheries Development Fund in the Fisheries Act of 2003 has significantly enhanced fisheries management. The Fisheries Development Division has established a sustainable funding mechanism through a “Retention Scheme” that supports fisheries management and research activities in the country. However, this scheme has been suspended since 2016.

The fishing communities are participating in monitoring, controlling and surveillance activities and beach sanitation and hygiene. Fish processing plants use improved fish handling and processing methods and the Fisheries Development Division is the competent authority on issues pertaining to fish quality assurance. To a great extent, fisheries management and research activities have been strengthened in the three countries because they are regionally coordinated by the Lake Victoria Fisheries Organization.

9.5 Recommendations

- The government should continue to review the Fisheries Policy and Act in order to accommodate new developments in the sector. Currently, there is an updated National Fisheries Policy of 2015. The fishing communities should be facilitated and empowered so that they can establish fishermen's associations and Savings and Credit Cooperative Societies (SACCOS) from the beach level to the regional level.
- The Government's efforts to monitor fish post-harvest losses should be expanded to cover all the three commercial fish species and this intervention should start from the fishing grounds up to the markets. In addition, sensitization of fishing communities on issues relating to improved fish processing, handling and processing methods, beach sanitation and hygiene should continue in all the riparian districts so as to guarantee socio-economic benefits to the communities.

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Chapter 10
Financing Mechanisms for Lake Victoria Fisheries Management

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Abstract Management of fisheries in the Lake Victoria Basin is faced with a multitude of natural and anthropogenic pressures such as over-fishing, eutrophication, declining water levels, soil erosion, sedimentation, water hyacinth infestation and encroachment into fish breeding and spawning areas. The idea of establishing a trust fund, which would contribute to the sustainable management of the lake fisheries and conservation of the lake's ecosystem, was first conceived during Phase I of the Lake Victoria Environmental Management Project (LVEMP I). This occurred by commissioning a consultancy to study the feasibility of establishing a Fish Levy Trust Fund. The Fund was intended to improve the livelihoods of fishing communities and sustainable management of the fisheries resources through enhanced revenue collection and disposal for essential monitoring, management and effective enforcement. Through a lengthy process of consultations and stakeholder engagement during Phase I (1997–2005) and Phase II (2009–2017) of LVEMP, the Lake Victoria Fisheries Trust Fund (LVFTF) was finally established in 2016 as a way of developing a sustainable funding mechanism to conserve biological diversity and ensure socio-economic welfare of communities that depend on the lake for their livelihood. This chapter therefore presents the chronology of events that led to the establishment of LVFTF, and describes the rationale, organizational structure and functions of the Fund.

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10.1 Introduction

Lake Victoria basin is home to about 35 million people, representing an estimated 30% of the population of the riparian countries of Burundi, Kenya, Tanzania, Rwanda and Uganda (Lake Victoria Basin Aquatic Biodiversity Meta-Database). The lake basin consists of Lake Victoria, the second largest lake in the world with an area of 68,800 km^2 and numerous satellite lakes and rivers. Fisheries is the major source of livelihood to lake basin communities, and supports the economies of the riparian states through export of fish and fishery products to regional and international markets. The lake provides water for hydropower generation, domestic, agricultural and industrial use and modulates local climate. The lake's shore and the basin have extensive wetlands, which are rich in biodiversity, providing important fish habitats and reduce excess nutrients that would pollute the lake.

The lake has maintained a relatively high fish production since the Nile perch boom in the early 1990s. The estimated total fish landings from 2005 to 2014 have been about 1 million metric tonnes with beach value increasing from about US$ 550 million in 2011 to about US$ 840 million in 2014 (LVFO 2014). In Tanzania, the total export of Nile perch and its products from 1997–2004 was 79,646 tonnes, valued at US$ 212,165,184 (F.O.B. value), of which the government received a total of US$ 13.11 million as royalty. The contribution of lake fish and fishery products to the Gross Domestic Product (GDP) was estimated at 2.8% in 2016. The export and GDP values show the importance of fishery resources to the national economy, socio-economic development, biodiversity conservation, and environmental protection.

Furthermore, based on 2015 statistical report, the Lake Victoria fishing industry contributed a substantial revenue to the Government through export, which was 41,059 tonnes and valued at US$ 259,286,762 (Fisheries Development Division 2015). However, Lake Victoria has been experiencing an intense pressure from human activities and natural processes with serious environmental implications. The most obvious of the challenges are the disappearance of indigenous fish species, eutrophication due to industrial and municipal waste pollution, illegal fishing practices, overfishing, encroachment into the fish breeding areas and the general degradation of the lake's ecosystem. All these environmental challenges caused a serious loss of income on the part of the fishermen and traders, the loss of food/protein and the loss of foreign exchange by the Government (GoK/GoU/GoT 1996).

Nevertheless, the fishery resources of Lake Victoria are being threatened by an increasing demand for fish for both domestic and foreign markets. The resources can be exploited by anybody. Cowx (2005) links this with the proliferation of processing plants and the demands they impose on supplies and concludes that the fisheries of Lake Victoria are over exploited.

10.2 Financing of Fisheries Management Through Decentralization and Retention Schemes

Fisheries management activities in Tanzania have historically been hampered by insufficient funds from the period prior to independence in 1961 to date. On the other hand, illegal fishing practices, overfishing, poor fish handling, processing and preservation methods, poor access to roads and other transport facilities which were prevalent during the colonial era, have continued to provide management challenges to the lake.

In order to strengthen fisheries management activities in the country, the Government of Tanzania introduced a decentralised system for management of fisheries in the 1970s. Under this new setup, the local authorities were given certain responsibilities. However, the scope and responsibilities of the local authorities have been increasing since then. These authorities are currently in charge of issuing fishing licences to fishermen, registration of fishing vessels, collection of data on fisheries, law enforcement, involving people in the conservation of aquatic resources, and coordination of extension services, among others (United Republic of Tanzania, URT 1997).

With those changes, the Fisheries Development Division remained with responsibilities of formulating policies and overseeing their implementation, sectoral planning and budgeting, formulating and reviewing laws, law enforcement, licencing and collecting revenue, among others. However, all these changes have not resulted into the expected outcome of reducing over-fishing, enhancing conservation of fish biodiversity and conserving the environment, among others.

Therefore, the experience gained over the years showed that alternative mechanisms and sources of funds are required to finance fisheries management activities in order to sustain fishery resources for the benefit of the people and the nation. Based on these facts, the Government of Tanzania introduced a retention scheme as a mechanism of boosting funds to the sector for the purpose of developing it since 1996 to mid 2016. However, the amount of money accrued from retention scheme was not sufficient to finance fisheries management, research and training, which exemplified the need for establishing a self-financing mechanism for fisheries management and ecosystem conservation. Nevertheless, the retention scheme is no longer operational, as it was abolished by the Government since mid-2016.

The retention scheme is thus an arrangement that allows a sector or department to use all or part of the revenue collected for the furtherance of its activities. Retention is allowed for sectors that generate income, however, the retention scheme was not legalised. The Treasury maintains that the main purpose of the retention scheme is to re-invest the funds in the sector from which the revenue was collected with the aim of generating more revenue from that sector.

10.3 Development of Lake Victoria Fisheries Trust Fund as a Self-Financing Mechanism

Despite the Government strategies of establishing a decentralization system and a retention scheme, the management of fisheries resources in both marine and freshwater bodies was still found to be ineffective. Therefore, a self-financing mechanism was regarded as the only strategy towards sustainability of fisheries resources. A study was subsequently commissioned under the support of the LVEMP I (1997–2005) to "lay the foundation for generating public revenues from fishing and using them to sustain further environmental protection activities in the Lake Victoria Basin". This study was one of the planned activities within the Policy and Institutional Framework component of LVEMP I. The study was carried out in 2000 by UK consultants MacAlister Elliott and Partners in association with M-Konsult of Tanzania (LVEMP 2002). The scope of the study was focused on:

- The analysis of current revenues and revenue collection in the Fisheries Sector;
- proposal of options for a revised system of revenue collection;
- analysis of the impacts and effects of the proposed revised system, and
- proposal for the disposal of collected revenues.

The study revealed that the collection of export royalty was effective and efficient. The analysis of maximum possible revenue obtained from the fisheries as tax indicated that the maximum revenue was 1.4 times higher than that which was charged on the fisheries and over 3 times higher than that which was taken by the state.

10.3.1 Local Government Revenue

The study revealed that the Local Governments were collecting less revenue than they should have been collecting. It was estimated that the annual Local Governments' collection was Tshs 656,300,000 (USD 821,628). This amount could be increased to Tshs 1,603,500,000 (USD 2,007,436) with an improved revenue collection system. Furthermore, it was estimated that the maximum annual Local Governments' collection could be Tshs 2,315,500,000 (USD 2,898,796), which is 1.4 times higher than the estimated annual revenue collection of Tshs 656,300,000 (USD 821,628). It was also observed that, human resources at the district level were not adequate to collect revenue 24 h a day. Furthermore, the structure of remuneration at the district level did not make the staff work efficiently.

10.3.2 Central Government Revenue

The export royalty is normally charged at a fixed tariff per each kilogramme of Nile perch and its products. This system does not allow for any further discussion about appropriate levels of the price of fish that is exported abroad. Evasion of payment of royalty for the formal export of fresh and frozen Nile perch products is not easy. Under-declaration of the weight of fillets is considered unlikely to happen under the prevailing market conditions, as irregularities in shipment weights run the risk of the consignment being rejected or delayed in the European countries, with potentially serious losses on the part of the exporter. The present system of contracting private agents is not transparent and legally permits a very significant proportion of the "collected" revenue to be appropriated as profit by agents. In addition, fishermen incur significant losses of revenue through the use of weighing scales, which have been tampered with by fish traders.

Currently fishing activities are not adequately controlled. It is suggested that these activities be controlled by regulating, for example, the processing of the Nile perch by introducing a quota or any other management measure for the long-term sustainability of the Nile perch. However, the Industrial Fish Processors have established a Memorandum of Understanding (MoU) to collaborate with Riparian Governments to ensure sustainable fishing of Nile perch by adopting self-policing on slot-size whereby a Nile perch of more than 85 cm long and less than 50 cm shall not be processed in any fish processing establishment in Kenya, Uganda and Tanzania.

Following the results of this study, the Government considered and implemented the consultants' recommendations of which the three national reports on the Lake Victoria Fisheries Trust Fund from the riparian countries were harmonized and submitted for consideration by the members of the Regional Policy and Steering Committee (RPSC) of the LVEMP. Subsequently, the RPSC directed each riparian state to establish the Lake Victoria Fisheries Trust Fund in a resolution of a Joint Communiqué of the Council of Ministers of the Lake Victoria Fisheries Organization issued in Kampala, Uganda on 28th May 2010 (LVFO 2010). The study therefore laid down the foundation for establishment of the LVFTF of which the constitution of the Fund was developed and named as the Trust Constitution of the Lake Victoria Fisheries Trust Fund (URT 2016).

10.4 The Lake Victoria Fisheries Trust Fund (LVFTF)

The proposal for establishing the Lake Victoria Fisheries Trust Fund (LVFTF) was made on the basis of the following two key premises: (1) Revenue streams and (2) Local Government autonomy. The primary Central Government revenue from Lake Victoria fisheries is export royalty, while the Local Government Authorities' revenue is accrued from fish licenses, fees for registration of fishing boats, fish permits and other fisheries related activities. However, it was observed that, once the revenue is collected from fisheries resources only very little or no money is returned to the community to sustain these resources.

Therefore, mainstreaming the LVFTF to the Local Government Authorities (LGAs) of the riparian districts of the Lake Victoria was purposely made due to the fact that it is difficult and politically wrong to force the Local Governments to spend the revenue collected from the fisheries in a certain way, for example, to make contributions to the central or regional fund.

10.4.1 Funds Mobilization and the Financing Mechanism Under LVFTF

Sustainability of the LVFTF is reliant on:

- The contributions from different sources such as voluntary contributions from Trustees, other persons, Development Partners, Governmental (Central and Local) Agencies, charitable organizations and Co-operative Unions
- Voluntary contributions from fishing vessels, fisherfolk and exporters of fish and fishery products
- Grants, bequeaths, donations and gifts
- Investments and interests accruing from such investments
- Friends of Lake Victoria
- Fund raising programmes
- Voluntary contributions from the private sector
- Income from sales of Trust assets

Nevertheless, the riparian districts in the Lake Victoria basin have agreed that LVFTF should receive funds from Local Government Authorities at a proposed rate of 5% of the total revenue collected from fisheries resources.

There are five fundamental concepts behind the Lake Victoria Fisheries Trust Fund:

- Provide reliable support for promoting an enabling environment for effective participation and involvement of the local communities in the conservation and sustainable management of the fisheries resources and biodiversity of the Lake Victoria Basin and to ensure they benefit from such conservation and sustainable management;
- Provide reliable support for projects and research which promote the conservation of biological diversity, aquaculture and sustainable use of fisheries resources in the Lake Victoria Basin and contribute to the promotion of the economic growth and social welfare of the communities in the region;
- Support consultancies for collection and dissemination of information and advice concerning the Lake Victoria Basin and their global conservation value;

- Liaise and collaborate with government agencies, communities, civil societies and the private sector in the sustainable management and utilization of Lake Victoria Basin fisheries resources; and
- Advocate for policies, regulations and laws that are designed to promote sustainable development and conservation of fisheries resources and environment of the Lake Victoria Basin in Tanzania.

10.4.2 Structure and Functions of the Lake Victoria Fisheries Trust Fund

The Lake Victoria Fisheries Trust Fund is administered by an Executive Director and the LVFTF Management Team. At its apex, the Fund is managed by the Board of Trustees, with one representative from the Ministry responsible for Fisheries, Ministry responsible for Regional Administration and Local Government, Ministry responsible for Water, International Conservation Agency active in Tanzania, a national NGO with interest in natural resources conservation, Civil Society Organisation, higher learning or research institution with focus on fisheries, private sector (fisheries), Local Government Authority (Riparian LGAs on rotational basis) and the LVFTF Executive Director (Secretary to the Board and Ex-officio).

10.4.3 Power and Duties of the Board of Trustees

The Board of Trustees has the powers in addition to all powers given to it by law (URT 2016), as follows:

- To approve Staff and Financial Regulations of the Trust;
- To approve Operational Manual of the Trust; to raise money on the security of the Trust property, receive and manage funds with the overall objective of enhancing resources for sustainable use of fisheries resources in the Lake Victoria Basin;
- To mobilize resources from stakeholders including donor communities, Government and other financing institutions;
- To support development of fisheries industry, human capital development and natural resources sustainability with stakeholders' involvement;
- To operate as a fund management institution that continuously seeks to sustain its funding base through prudent investment of its reserves and expanding its revenue streams;
- To approve budgets, statutory and other expenses as may be incurred in relation to the Trust from time to time;

- To demise or let in good faith (bona fide) the property of the Trust for such terms and at such rent or for a gift and subject to such provisions as to the Trustee shall appear desirable;
- To appoint, remove or suspend and pay employees or persons as it may from time to time be deemed necessary and to determine their duties and powers and to fix their salaries and remuneration;
- To approve terms of remunerations and any other fringe benefits (if considered necessary) to Trust staff or any of them of such amount as deemed fit for the proper and efficient discharge of duties;
- To employ any agent of proven credibility to transact all or any business of whatever nature required to be done in furthering the purposes of this Trust. The Trustees shall not be responsible for the default of any such agent or any loss occasioned by their employment;
- The Trustees shall at all times safeguard the Trust property and take such legal or other proceedings as they may think necessary for the recovery or protection thereof; and
- To do such other lawful acts and things as are incidental to or conducive to the attainment of the general purposes of this Trust.

10.4.4 LVFTF Committees and Their Functions

The LVFTF Board of Trustees may delegate some of their powers to Standing Committees consisting of Trustees or other people as they deem fit. Such delegation lasts until the tasks assigned have been completed to the satisfaction of the Board. Members of the Committees may serve at the pleasure of the Board and the activities of which shall at all times be subject to the ultimate direction of the Board. According to the constitution of the LVFTF (URT 2016), the Standing Comittees and their functions entail the following:

- **The *Investment Committee*** shall comprise one or more Trustees and other individuals shall oversee the investment of assets held by the Trust and make recommendations to the Board of Trustees. Members of the Investment Committee shall serve without compensation but shall be reimbursed for their reasonable expenses.
- ***The Grants Committee*** shall be composed of one or more Trustees and other individuals who shall serve to consider and recommend to the Board of Trustees the charitable recipients that will receive grants from the Trust. Members of the Grants Committee shall serve without compensation but shall be reimbursed for their reasonable expenses.
- ***Local Advisory Committees (LACs***) may be established in each LGA where the Trust funded projects are being implemented in order to provide advice and guidance. The LACs will function as sub-committees of the Trust and serve as advisory bodies within their respective areas and shall have no decision-making

authority nor have powers to enter into contracts, commitments or lawsuits on behalf of the Trust. The Trustees shall give regard to advice as may be given by the committees but shall not be obligated to act on such advice. Members of the Local Advisory Committees shall serve without compensation but shall be reimbursed for their reasonable expenses.

10.4.5 Executive Director, and Functions

The Executive Director is appointed by the Board of Trustees as per the Constitution (URT 2016). The functions of the Executive Director are as follows:

- Organizing and participating in the meetings of the Trustees as the Secretary to the Board, but without a vote. The Executive Director shall keep minutes of the meetings of the Trust, execute all resolutions and decisions of the meetings of the Trustees, and, subject to the directions of the Trustees, shall in general supervise and control all the Trust's day-to-day business and affairs;
- Organizing Annual Consultative Forum to involve Local Advisory Committees and other relevant stakeholders as shall have been established under the Trust Constitution;
- Ensuring that the Trustees are kept up to date on all of the Trust's activities, and actual and potential problems faced in implementation thereof;
- Preparing Business Plan, Operational Manual, Staff and Financial Regulations of the Trust and operationalize as directed by the Board of Trustees;
- Establishing and maintaining a regular process for determining and meeting the challenges and objectives of the Trust;
- Planning, developing and coordinating all programme components and courses of action for implementing those programmes;
- Co-ordinating all activities of the Trust to ensure that the LVFTF Management Team under the Fund, implementing agencies and other groups achieve the set outputs;
- Advising the Board of Trustees on matters related to sustainable management and development of resources in the Lake Victoria Basin;
- Preparing and reviewing the budget of the Trust, annual work plans, staffing plans and estimate and monitor expenditures;
- Presenting to the Trustees an annual budget at a Board meeting 90 days prior to the end of the financial year. Supplemental budgets may be presented at any Board meeting;
- Ensuring quality assurance and control activities related to the programme components of the Trust;
- Preparing and submitting quarterly, semi-annual and annual progress reports, audit reports to the Board of Trustees, donors and other stakeholders on the activities of the Trust;

- Signing contracts and other instruments that the Board of Trustees has authorized;
- Developing grants guidelines and procedures for soliciting, reviewing and awarding grants for projects to be funded by the Trust; and
- Performing all other relevant duties that the Board of Trustees may assign him/her from time to time.

10.4.6 The LVFTF Management Team

The Board has powers to establish a Management Team for the LVFTF, composed of Executive Director and such number of employees as the Board may determine from time to time. The LVFTF Management Team shall be under the supervision of the Executive Director. The specific roles and responsibilities of the LVFTF Management Team shall be, but not limited to:

- Ensuring that all projects undertaken by the Trust are effectively implemented and managed in adherence to approved work plans and policies;
- Undertaking the day-to-day implementation of activities of the Trust based on individual job description and Terms of Reference.

10.4.7 Possible Risks in Running LVFTF

The envisaged risks are as follows:

- The Local Governments could choose not to use their revenue for co-financing projects with the LVFTF;
- The LVFTF and indeed the entire economic status of the fisheries would depend on the continued and successful operation of the processing and export industry. If this industry failed, the LVFTF would fail, too.

10.4.8 Revision of the Legal Framework

The establishment of the LVFTF and the revision of revenue collection mechanisms need to be legalised by making amendments to some of the existing laws so that the Fund can be established in a lawful manner. It has already been pointed out that the LVFTF would receive funds from a Local Government Authority, which were levied under Fisheries Act No. 6 of 1970 (repealed by the enactment of the Fisheries Act of 2003). The establishment of the Fund would necessitate amendment of the

Fisheries Act No. 22 of 2003 because the LVFTF was not incorporated in the current Fisheries Act. It has been proposed that the Government should amend the Fisheries Act No. 22 of 2003 to accommodate the establishment of the LVFTF.

The amendment of the law would state the main objective of the LVFTF, which is to generate revenue from fishing and use it to carry out further environmental protection activities in the Lake Victoria Basin. The objective is in line with the overall goal of the National Fisheries Policy of 2015, which is: "*to contribute to national poverty reduction objective through sustainable management and utilization of the fishery resources*" (URT 2015).

However, the Joint Communiqué of the Council of Ministers of the Lake Victoria Fisheries Organization (LVFO) issued at Munyonyo, Kampala, Uganda on 28th May 2010 urged the Partner States to each establish and operationalise the Lake Victoria Fisheries Trust Fund. Based on this Joint Communiqué, the Fisheries Development Division shall incorporate this Fund into the Fisheries Act in the course of its review. Furthermore, the LVFTF was registered by Administrator General of Trustees, Registration, Insolvency and Trusteeship Agency (RITA) in October 2016.

The findings of the Fish Levy study indicated that royalties from fish exports were higher than any other royalties (LVEMP 2002). At the local level, the revenue accrued from fish levies. The collection of revenue by the Central Government was efficient and effective. The collection of revenue by the Local Governments was efficient but not effective. The system of using private agents was not transparent and legally permitted a very significant proportion of the revenue that was collected to be appropriated as profit by the agents. Fishermen lost revenue because traders used weighing scales which were tampered with. Based on the findings of the study it was concluded that:

- A revised system for contracting levy agents should be formulated and implemented. This should include transparency in public tendering and establishment of minimum contract values on the basis of a 30/70 (or better) division of the revenue that is expected to be collected between the agent and the Local Government. The value of contracts should be fixed. To date the system is yet to be revised.
- In the short term, no changes should be made to the mechanism for the collection of revenue used by the Central Government. In addition, in the medium term the implementation of a quota-based system for the management of Lake Victoria should be considered. Consultations, analyses and policy development should be done before such a system is created.
- A special fund for environmental protection activities should be established, as already proposed.
- The LVFTF should receive money from revenue accruing from fisheries activities and the amount of that money should be determined by the Board of Trustees. The LVFTF should receive direct contributions from the Local Governments.

10.5 Conclusion

The socio-economic gains to the riparian fishing communities in terms of income, employment and food are enormous. These benefits can only be guaranteed with the presence of effective fisheries management tools that are supported by a sustainable funding mechanism such as a combination of the “Retention Scheme”, which has been found to be efficient and effective, and the LVFTF. The Government should therefore legalize the Fisheries “Retention Scheme” in order to guarantee a reliable source of funds for fisheries management, research and environmental protection activities in the country. In addition, the Government should ensure that the National Fisheries Development Fund that has been incorporated in Fisheries Act No. 22 of 2003 is fully operational.

The Fisheries “Retention Scheme” received money mainly from the Nile perch and *Rastrineobola argentea* (dagaa) export royalties. The sustainability of the “Retention Scheme” depended on the sustainability of the Nile perch stocks and dagaa. If the Nile perch and dagaa stocks collapsed the retention scheme would also collapse. Therefore, more effective management tools such as quotas for individual processing plants and a limited number of fishing vessels and gears should be introduced and collaborative fisheries management should be strengthened.

10.6 Recommendations

- The Fisheries “Retention Scheme” is no longer in existence. It was removed from the Government budget in 2016 as it was not backed up by any law. Based on the importance of the “Retention Scheme” to the Fisheries Development Division, the scheme should be incorporated into the national laws. The purpose should be to increase revenue collection in the fisheries sector and to use part of revenue to further sustain fisheries management, research and environmental protection activities in the Lake Victoria Basin.
- The establishment of the Lake Victoria Fisheries Trust Fund should be mirrored in all other water bodies in Tanzania, meaning that it is highly recommended that all other water bodies establish a similar Fund.

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Chapter 11
Co-management of Lake Victoria Fisheries

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Abstract There have been concerns about the declining fish catches and fisheries ecosystem health for a number of fisheries including Lake Victoria. Consequently, a co-management system has been introduced as a means of, among others, reversing the declining catches. It is hypothesized that non-involvement of fishers in the management of the lake's fisheries is a major reason for the ever-decreasing catches. This chapter discusses this particular management regime and its application in the lake's fisheries. The analysis is based on data collected by the Fisheries Division since co-management was introduced in the lake in 1998. The chapter traces the lake's fishery management since the pre-colonial to the post-colonial period. It presents the aim and rationale for managing the lake's fishery, the structure of the management and roles of governors. It also analyses trends in illegal fishing practices as well as enforcement performance. The argument here is that co-management has helped in bringing on board fishers and this has enabled laws and regulations to be implemented in a much better way than they were under a central-command system. The chapter subsequently concludes that the involvement of fishing communities in the management of fisheries has created a forum for the exchange of ideas, knowledge and experience on the resources. This strategy has made the communities understand the importance of compliance to the law and regulations and effective management measures.

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11.1 Introduction

The sustainability of fishery resources and the accruing benefits, require sound management measures agreed upon by stakeholders and backed by legislation. Over the years, the number of people living around or near the lake has increased side by side with the increase in industries and other socio-economic activities like agriculture, mining and livestock keeping. These developments and activities have brought about changes in the water quality, fisheries biodiversity, wetlands and land use. Fish stocks have been decreasing, biodiversity has declined and water quality has deteriorated (Government of Kenya, GoK/Government of Uganda, GoU/ Government of Tanzania, GoT 1996; Mkumbo 2002). There are sectoral Acts and Regulations for addressing these issues. However, they have not been effectively enforced because of several reasons, including poor governance with little or non-incorporation of respective stakeholders in the management of the fishery.

However, there is an Act and Regulations to ensure effective management of the fisheries resources and protection of the lake's environment. The law provides for the protection, conservation, development, regulation and control of fish, fish products, aquatic flora and products thereof, and for matters incidental thereto and connected therewith. There are inclusions in the Fisheries Regulations, which have been enacted specifically for Lake Victoria. These include those that prohibit the use of destructive fishing gears and methods like beach seines, gillnets with mesh size less than 6", dagaa nets with mesh sizes less than 10 mm, water splashing and other harmful fishing practices like the use of poison, trolling, weirs and diving. The law prescribes penalties for any person who is found guilty of contravening the Act or any Regulation made under it. If one violates the law for the first time, the punishment is a fine of Tsh 300,000 (US$ 135) or a 3 years' jail sentence or both. If one violates the law for the second time, the punishment is Tsh 500,000 (US$ 230) or a five-year jail sentence or both.

Until around 2000, the enforcement of the Fisheries Legislation, which was in place for the sound management of Lake Victoria resources and environment, was weak because of, among others, the top-down approach where the government (central and local) was the only institution involved. This resulted in persistent increased illegal fishing practices and destruction of the environment.

The failure of the "top-down or go-it-alone system" was due to the following reasons:

- Inadequate fisheries staff, water and land facilities to run necessary management operations.
- Resource users were not participating in the formulation of the fisheries management policies, objectives and measures for the sustainable utilization of the resources, conservation of biodiversity and environmental protection. Also, they were not taking part in the evaluation of these policies, objectives and measures.
- The Government never considered resource users' views and opinions on resources management.

- Management by the Government inculcated into the communities the feeling that they do not own the resource. Consequently, the communities did not involve themselves in the conservation and protection of the resources and environment.
- The centralized system discouraged partnerships, sharing of power and responsibilities with the stakeholders.
- Existence of poor relationships between Government staff and members of the communities undermined the efforts and measures, which were put in place by the Government to sustain the resources, to conserve biodiversity, and to protect the environment.
- Huge financial resources were required under the centralized system to meet the management costs, which adversely affected management activities because funds were, and still are not sufficient.

Being aware of the effects of excluding communities in the management of the resources, the Government developed and included a co-management provision in the National Fisheries Policy of 1997. The policy regarded communities as a vital part of the planning, development, and management of fisheries resources in order to achieve the desired objectives, and to ensure the sustainability of the resources with the accrued socio-economic benefits.

Implementation of the provision of the Policy on co-management was undertaken during the Lake Victoria Environmental Management Project Phase I (LVEMP I) between 1997 and 2005. This was done through the establishment of Beach Management Units (BMUs). The BMUs subsequently got legal recognition in the Fisheries Act No. 22 of 2003 and Fisheries Regulations of 2009. BMUs are the foundation of fisheries co-management that bring together everyone involved in fisheries at a landing site (boat owners, boat crew, traders, artisanal fish processors, boat builders and repairers, net repairers and others) to work with the government and other stakeholders in managing fisheries resources and improving the livelihoods of members of the community. This collaborative management approach in the management of the Lake Victoria fisheries resources was pioneered on the Tanzania part of the lake, and later to the other riparian countries (Kenya, Tanzania and Uganda) sharing the lake under the coordination of the Lake Victoria Fisheries Organization (LVFO).

During the implementation of the Fisheries Management Plan Project (IFMP 2003–2008), BMUs which were established during LVEMP I were re-formed. The re-formation was undertaken in the entire lake. During this time, the riparian countries also formulated BMU Guidelines for Lake Victoria. These were adopted and harmonised to form a Regional (Lake wide) BMU Guidelines. The reformation exercise reduced the number of BMUs established during LVEMP I from 511 to 434.

The capacities of those BMUs were enhanced during the IFMP through training in various areas ranging from orientation of BMU leaders on BMU operation, civic education, leadership and good governance, fisheries co-management, fisheries management and formulation and implementation of projects, bylaws, work plans and reporting. The objective of capacity building of BMUs was to enhance the performance of the BMUs Leadership in the execution of their roles and responsibilities in the fisheries management in a transparent and accountable manner to all members.

The fisheries field extension officers were charged with mentoring the established BMUs to ensure that they attain a level of excellence in the execution of their duties and responsibilities.

The adoption of co-management in the management of fishery resources by the government was deemed necessary because of numerous advantages, including the following:

- Fishermen acquire more control over the fisheries, which they effectively own as a community, and there is a greater trust between them and the Government. The collaboration between the two has the following benefits:
  - Fishermen are motivated to take a long-term management perspective (sustainability) and enforcement of the regulations is more effective because they now have a high level of acceptance and so compliance is also high. As a result, the costs of enforcing the regulations by the fisheries management institutions are reduced.
  - It guarantees a rapid recovery of fish species that are otherwise in danger of extinction.
  - Fishing communities are empowered to decide on the wise use of the resources.
  - Fishing communities have a sense of ownership over the resources.
- Fishermen cooperate with the Government in planning, development, protection and conservation of the resources and the environment.
- Fishermen share the costs and benefits of improved management, thereby reducing the costs to the Government.
- Conflicts among fishermen are efficiently resolved among themselves.
- Fishermen and Government authorities are willing to share data and fishermen's understanding of fisheries (indigenous knowledge) is taken advantage of in the management of the resources.
- Fishermen usually organize themselves so as to maintain and enhance their position among other stakeholders, e.g. water users and fish traders.

In Lake Victoria, the management of the fisheries can best be understood by looking at three eras. These are the pre-colonial era, the colonial era and the post-colonial era. Under each era, there were regulations, which aimed at ensuring the sustenance of the resources in the interest of the communities in particular and the nation in general. The type of challenges facing fishery resources and the dynamism of the industry necessitated the development of the regulations in each era. This chapter, therefore, presents trends in the management of the resources for all the eras and analyses the monitoring, control and surveillance results with regard to law enforcement and compliance to fisheries regulations.

11.2 A Chronological History of Management Regulations

11.2.1 Pre-colonial Era

This refers to the period before the year 1885 when Tanganyika became a German colony. There is no record on how formal fisheries management was implemented during this time. However, the fishing communities around the lake had their regulations (Kateka 2010). These regulations included the territorial use rights whereby families living closer to a particular area of the lake fished in that area without interference from others; they also had access rights to areas adjacent to their residences. The communities fished using simple gears (traps, baskets, spears) and crafts for subsistence requirements, and occasionally, they exchanged fish for other food items like maize flour (Onyango 2004).

11.2.2 Colonial Era

The colonial period lasted from 1885 to 1961, under the Germans and the British. During this period, cash crops (tea, coffee and cotton) were introduced and intensified around Lake Victoria. Towns were also set up as trade centres. The towns were Mwanza (on the southern side), Musoma (on the eastern side) and Bukoba (on the western side). Transport and communication facilities were established to connect these towns, which were also administrative centres.

Consequent to these developments and the growth in population in the region, there was a high demand for fish. Thus, fishing pressure on the fish stock intensified, thereby causing a significant decline of fish species, especially the Nile tilapia, *Oreochromis niloticus* (Ligtvoet et al. 1995a, b). The decline of fish stocks prompted researchers to recommend a ban on the use of fishing nets with mesh size less than 5″. This was legislated in 1950 but it was never enforced in the then Tanganyika until 1953. The enforcing body was the Lake Victoria Fisheries Service (LVFS), which was established in 1947. At the time, there were two ordinances (Trout Protection Ordinance of 1929 and Fisheries Ordinance of 1950), which however were not applicable to Lake Victoria.

11.2.3 Post-colonial Era

After independence in 1961, the Government's recognition of the importance of Lake Victoria fisheries to the communities and the nation as a whole was manifested by the creation of the Fisheries Development Division in 1965.

Over the years, a national legislative and policy framework has been developed to allow the country's participation in international and regional bodies on affairs related to fisheries. At the international level, the country is signatory to the FAO Code of Conduct for Responsible Fisheries, which recommends Monitoring, Control and Surveillance to be proportional to the level of fishing activities. At the regional level, Tanzania is signatory to the LVFO Convention of 1994.

At the national level, there is a comprehensive law, the Fisheries Act no. 22 of 2003 and Fisheries Regulations of 2009, which cover control and access to the fisheries, gears used, protection of habitats, fish quality standards, establishment of surveillance units and a fisheries development fund, aquaculture development, and the regulation of cross-border fishing and trading.

Authorised personnel and procedures are outlined in the law. The authorities are empowered to inspect and search, seize, detain, destroy illegal gear, halt aircrafts and vessels, inspect and search of vessels, houses and premises, seizure and detention of vessels, fish and fish products, the selling of seized fish and products, arrest and prosecute people who contravene the Act and its Regulations. They are also empowered to inspect fish and fishery products to ensure hygiene and good quality. They have been empowered to impose fines on offenders. The Beach Management Units (BMUs) and the fishing community groups are recognized by the Act and their roles and functions are spelt out in the Fisheries Regulations of 2009, which include conducting monitoring, control and surveillance in areas of their jurisdiction (beaches and adjacent waters). The enactment of the Act (and repealing of the Fisheries Act no. 6 of 1970) with the respective Regulations was prompted by the developments in the fishing industry, which could not be covered by the previous Act and Regulations. Formally, from time to time, it was necessary to amend some of the fisheries principal regulations to address the challenges and the dynamics of the fishing industry.

11.2.4 Flexibility of the Law and the Powers of Authorised Officers

Under the law, the management of fisheries is the responsibility of the Fisheries Development Division, under the Ministry of Livestock and Fisheries Development.

Under the Fisheries Act No. 22 of 2003, the powers of its enforcement have been vested in authorised officers, including the Director of Fisheries, all fisheries officers, all members of the BMUs and other persons, who must be authorized in writing by the Director. Like the former law, the new law is flexible in the sense that any management action, which is to be taken, can easily be incorporated in the Fisheries Regulations under it.

11.2.5 *Aims, Objectives and Rationale for Management Regulations*

The overall goal of the National Fisheries Sector Policy and Strategy Statement (1997) is to promote conservation, development and sustainable management of fishery resources for the benefit of the present and future generations. The implementation of the policy is done through the law and the regulations. The law and the regulations are amended or changed to control threats to resource biodiversity, the environment or the health of consumers whenever scientific facts obtained through research by a formal institution indicate that the fishing gear and techniques, fish handling, processing, packaging and distribution are threatening the sustainability of fishery resources, biodiversity, the environment's and consumers' health. Based on this principle, there have been various changes to the fisheries regulations since 1970 to contain challenges in the fishing industry over time. The first principal fisheries regulations were legislated in 1973, which was amended in 1978 and 1982.

11.2.6 *Management of Fisheries Resources*

Until about two decades ago, there were no fisheries policies. The present policy was developed in 1997, the objectives of which include: regulation, protection, promotion, conservation, development and sustainable exploitation and utilization of fish and other fishery products so as to provide food, employment, income and foreign exchange by exporting fish.

There are strategies contained in the policy to facilitate its implementation. The strategies cover the following areas: (a) Fisheries development and management, (b) Training, (c) Trade in fish and fishery products, (d) Aquaculture and (e) Research.

11.2.7 *Fisheries Act*

As stated above, until 1970 (9 years after independence), when the first Fisheries Act was enacted (Fisheries Act No. 6 of 1970), the fishing industry was not regulated by any law. The two Ordinances, which were in place by then, the Trout Protection Ordinance, Cap. 160 of 1929, protected the Trout fish in the cold streams of the Northern and Southern highlands for sport fishing purposes, while the Fisheries Ordinance Cap. 36 of 1950 provided for the establishment of Boards for specified water bodies, some of which were private properties. Such Boards were empowered to make their own management regulations. The management of national fisheries was, therefore, not given priority before independence.

Furthermore, Lake Victoria was not governed by the two ordinances. Section 2 of the Fisheries Ordinance defined “waters” as all territorial inland waters of the Territory, except the waters of Lake Victoria and its islands; and excluded all waters of the territory under private ownership. Section 30 of the ordinance stated that nothing in the ordinance or any provision made would have any effect in relation to the waters of and the islands of Lake Victoria (Fisheries Ordinance Cap. 36 of 1950). To this effect therefore, until 1970, fisheries management was conducted under administrative orders.

The Fisheries Act No. 6 of 1970 recognized the underdevelopment of the sector, and provided for the enactment of the principal fisheries regulations to regulate the industry whenever situations demanded so in order to contain threats to the sustainability of the resources. The first Principal Fisheries Regulations were put in place in 1973 and were replaced in 1978, then in 1982 and 1989.

Since 1982, important seven amendments were made to some of the regulations so as to address situations, which were posing threats to the sustainability of fisheries resources. The amendments, which were made include the following:

- Government Notice No. 5 of 22nd January 1982 proclaimed 24 areas of Lake Victoria as closed fishing areas from 1st January – 30th June of every month. The aim was to protect the brooder fish and the fingerlings.
- Government Notice No. 369 of 10th March 1994 prohibited the use of beach seines, under-sized mesh gillnets (less than 5″) and dagaa nets of (less than 10 mm). The main aim was to protect the immature fish of the respective fish species from being caught.
- Government Notice No. 370 of 7th October 1994 banned the use of trawlers for fishing in Lake Victoria. The purpose was the same as that in the second bullet above.
- Government Notice No. 189 of 6th June 1997 prohibited the possession of beach seines and fishing with this gear. This notice also increased the levels of fines, which would be meted out to offenders from 20 Tanzanian shillings to not more than one hundred thousand shillings.
- Government Notice No. 624 of 9th October 1998 made the fine stiffer to not less than three hundred thousand shillings or a 3 years’ jail term for first offenders or both, and for repeaters, not less than five hundred thousand shillings or a 5 years’ jail term or both.
- Government Notice No. 193 of 1st August 2003 prohibits fishing, possessing, processing or exporting or trading in a Nile perch fish of less than 50 cm or more than 85 cm total length.

The control of quality standards of fish became very important especially after the increase in the demand for fish on internal and export markets in the late 1990s. To this end, the Government Notice No. 300 of 2000 on the Regulations to control Fish quality standards was legislated. These regulations covered all aspects of fishing, handling, processing, distribution, hazard analysis critical control point (HACCP) in upstream areas, at establishments, at internal markets and exit points.

The amendments notwithstanding, the fishing industry had become so dynamic that a new law had to be enacted. In this respect, a “participatory” Fisheries Act No.

22 of 2003 was enacted. As was previously stated, this Act provides for co-management of the fisheries resources in all waters in the country, including Lake Victoria. Under this framework, stakeholders who take part in the management include: Fisheries Development Division, Local Governments, Non-Governmental Organizations, the private sector, fishermen, fish traders, fish processors, net and boat menders, and crew members. Their responsibilities are presented below.

11.2.8 Stakeholders' Responsibilities

Various institutions and stakeholders are involved in the implementation of the National Fisheries Policy. Their responsibilities are spelt out in the Policy so as to avoid clashes and overlap. The responsibilities are as follows:

The Fisheries Development Division
The overall responsibility of the Fisheries Development Division is fisheries management and administration, which entail the formulation of policies and oversight of their implementation, planning and budgeting, formulation and review of laws, law enforcement and surveillance, monitoring and evaluation of the sector's performance, management information systems, manpower planning and human resources development, extension services, research, training and curriculum development, co-ordination of other stakeholders, the licensing of fishing boats with more than 11 m length overall (LoA) and co-operation and collaboration with international organizations with regard to fish export. This has been the responsibility of the Division since it was established.

Local Governments
Under the decentralized system, the Local Governments are responsible for the registration of all fishing vessels, including those with more than 11 m LoA; issuance of vessel licences for vessels of less than 11 m LoA and to the fishermen who own such vessels. Others include co-ordination of extension services, law enforcement and surveillance, issuance of by-laws and participation in the formulation of regulations, collection of revenue from various sources, and involvement in the conservation of fishery resources and the environment. Also, proposition of areas with conservation and biodiversity values for subsequent gazettement as protected areas and involvement in the management of the areas that are conserved, for example, closed fishing and breeding areas, promotion of aquaculture and quality seed production. Some of the responsibilities have changed over time and are performed by fishermen, traders and processors.

Local Communities
The local communities are the direct beneficiaries of the resources and are in contact with the resources daily. Under the new law, the communities (through the BMUs) have been empowered to co-manage the resources with the Government. Their roles and responsibilities include conservation and management of fishery

resources, formulation and enforcement of by-laws, and collection of fisheries statistics. Also, oversight of beach sanitation and hygiene, resolution of conflicts, ensuring the security and cleanliness of the barges and other infrastructure and educating and raising the awareness of members of the communities on the effects of fishing malpractices on the resources, biodiversity and the environment.

Non-Governmental Organizations (NGOs)
Non-Governmental Organizations did not, in the past, take part in the management of the resources. They began participating in the management of the resources in 1997. Their responsibilities are: raising awareness, creation and provision of extension services, capacity building, technical assistance, financing of fisheries and environmental activities and promotion of participation of both men and women in the industry.

The Private Sector
The private sector enhances investment, improves business and general management in the fishing industry and revitalizes financing operations and the marketing of fishery products. All these entail the following responsibilities: sustainable harvesting and utilization of fishery resources, facilitation and financing investment in the fisheries sector, provision of employment and fishery inputs and services, and production and marketing of fish products, application of biodiversity guidelines in fisheries management, carrying out environmental impact assessments (EIA) in fisheries investment and investment in environmentally sound production technologies.

The Regional and International Community
These are partners in the sustainable development of the resources and their roles are: provision of financial assistance, capacity building, facilitating the implementation of international obligations and promotion of technical cooperation.

Government Agencies and Other State Machineries
The role of Government agencies and other state machineries is to assist in the management of the resources and in the conservation of the environment. With the commencement of more collaborative forms of management, these different actors have different responsibilities in the decision-making process and management, such as setting objectives, collecting information, formulation and implementation of measures and evaluation of those measures and objectives against indicators.

Table 11.1 shows changes in the management of Lake Victoria fisheries. The information in the table shows that a number of fisheries management roles are shared with fishermen, processors and traders (private sector). It should be noted that the setting of management objectives is done solely by the Government.

Table 11.1 Responsibility changes in the management of the fisheries

Position in decision making process	Role	1955–1975	1975–1995	1995–2005	2005–2015
Setting objectives		FD	FD	FD	FD
	Setting by-laws			F	F
Collection of information	Collection of statistics	R, FD	R, FD, LG	F, FD, LG	F, FD, LG
	Collection of experimental catch data	R, FD	R, FD, LG	R, F	R, F
Implementing measures	Registration of fishermen	FD	FD, G	F, LG	F, LG
	Enforcement of laws	FD	FD, G	F, FD, LG	F, FD, LG
	Collection of fees	LG	LG	F, P	F, P
	Conflict resolution	LG	LG	F, LG	F, LG
	Beach hygiene and sanitation	LG	LG	F	F
Evaluation of measures		FD	FD	F	F
Evaluation of management objectives		FD	FD	FD, F	FD, F

Legend: *F* Fishermen, *FD* Fisheries Division (Ministry responsible for fisheries), *R* Fisheries Research, *P* Private Sector, *N* NGO's, *LG* Local Governments

11.2.9 Enforcement Statistics

One of the major threats to the sustainability of the resources, conservation of biodiversity and protection of the environment, which was identified by fishermen, fish traders, fish processors and farmers at the consultative meetings, was the prevalence of fishing malpractices. The common one was the use of illegal fishing gear namely beach seines, under-sized mesh gillnets and dagaa nets of less than 10 mm and water splashing ("*Katuli*"). This gear has been banned since 1994. Efforts and energies in co-management since 1998 have been directed towards curbing illegal fishing practices including these gears.

11.2.10 Trends in Enforcement Performance

Patrols under co-management arrangement have been implemented since 1998 when the BMUs were introduced on Lake Victoria. Under this arrangement, BMUs conduct patrols in areas under their jurisdiction and collaborate with the monitoring, control and surveillance staff and other Government agencies when the Government organizes such patrols. BMU patrols are usually not facilitated by the Government. The BMUs have to meet the operational costs with funds sourced from the other income generating activities undertaken by the respective BMUs, which are mandated by Fisheries Regulations and respective village bylaws regarding Fisheries.

The outcome of the patrols from 1999–2016 conducted jointly by BMUs and Government (Fisheries Department) is presented in Table 11.2. Patrols conducted by BMUs alone are presented in Table 11.3 while those conducted by Government are in Table 11.4 for the period 1998/99 to 2016.

The trends in the number of confiscated gear are compared with bi-annual frame survey results (Figs. 11.1, 11.2 and 11.3).

Trends in the number of apprehended culprits and confiscated vessels are presented in Fig. 11.4. There is a positive correlation between immature Nile perch and the confiscated under-sized gillnets (Fig. 11.5). The same trend is true for immature Nile perch and confiscated beach seines (Fig. 11.6).

Gillnets Less with Mesh Size Than 5 Inches

There was an increasing trend from 1998 to 2016 (Fig. 11.1). There was a corresponding trend in the amount of gear confiscated to the number of immature Nile perch confiscated. In the 2 years after 2003, the number of confiscated immature Nile perch decreased about six times. With the exception of the 2 years (2004, 2005) the number of confiscated immature Nile perch has been more than or equal to the frame survey statistics (1998, 2000 and 2002). The frame survey statistics for 2004 are far bigger than the amount of gear confiscated. The number of gillnets less than 5 inches continued to rise until 2008 when it peaked and fell, but it has remained above 30,000 since 2014.

Beach Seines

The number of beach seines (BSN) confiscated has been decreasing with time after 1998 when the largest number (2395) was confiscated (Fig. 11.2), while the lowest number of BSN (724) was confiscated in 2004. Patrols have not yet had effects on the beach seines because the results of frame surveys showed that the beach seines which have been confiscated are fewer than those still in the field (Table 11.2) where the number of beach seines has remained above 1000.

Dagaa Nets of Less than 10 mm

Generally, there was a decreasing trend from 1998 to 2004, except for 2001 when the number of dagaa nets went up (Fig. 11.3). On the other hand, frame survey results show an increasing trend in this gear from 1998 to 2016 (Figs. 11.4 and 11.5), which is an indication that there is more of this gear in the field than the amount, which has been confiscated.

Culprits Apprehended in Relation to Confiscated Boats

Generally, the number of boats confiscated and culprits apprehended showed a similar growing trend from 1998 to 2003. However, thereafter, the number of boats decreased while that of culprits increased. The anomaly cannot be explained with the information available.

Table 11.2 Apprehended culprits, confiscated illegal gear and immature fish by the combined efforts of BMUs and the Government from 1998–2016

Culprits and gears/ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Culprits	25	131	172	175	140	149	162	481	410	380	484	236	170	193	167	31	92	172
BSN	2,395	769	1,221	951	1,182	948	724	1,735	1,138	1,112	745	591	528	1028	1277	152	507	216
GNs <5″	7095	6,086	11,628	20,623	20,277	3,625	3,853	4,524	18,908	33,700	9,845	6,000	5933	5075	17,491	2022	1307	31,394
DNs < 100 mm	1,096	390	578	2,805	300	229	211	96	205	113	275	30	5	83	295	319	432	60
Mono-filament		3		6	82	475	218	3,187	2,042	4,008	1,110	1,822	1588	4095	12,898	19,285	10,608	15,368
Katuli	201	138	281	207	135	232	42	24	29	6	1	2	16	4	9	27	16	111
Boats	2	35	94	35	62	52	32	74	131	457	87	74	68	125	111	269	253	150
Hooks			2200					3876		204,450								
Trawl net	4																	
Immature NP		800	2,759	10,614	10,748	3,700	6,294	12,912	45,170	45,019	73,852	72,622	62,906	27,023	26,469	32,111	7,972	26,437
Trawler	1																	
NT (kg)		26	2,560		64			26,655	11,741	10,410	18,260	5,750	4,295	1,340	1,268	1,585		36,894
Other species		58	422	546	390													
OBE	2							4	5	9	1		6	1	5	4		22
Lamps	13					9			4	75								
Dagaa (bags)								3,720	446	15,865	16,100		1,265	5,276	15,350			
Lawsuit								152	144	55	53	18	18	5	6	6		21
Rope (m)								25,200	55,100	73,140	144,640	194,684	101,476	206,240	336,685	248,990	378,560	1,386,693
Cast nets										1				12	3	16		

Legend: *BSN* Beach seine nets, *GNs* Gillnets, *DNs* Dagaa nets, *NP* the Nile perch, *NT* the Nile tilapia, *OBE* Out board engine. *Source:* Fisheries Division

Table 11.3 Apprehended culprits and confiscated illegal gears and immature fish by the BMUs from 1998–2005

Year	Culprits	BSN	GNs <5″	DNs <10 mm	Mono-filament	Water splashing (Katuli)	Boats	NP (KG)	NT (KG)	Other fish species (kg)
1998/1999[a]	14	36	409	16		16	2			
1999/2000[b]	127	225	2,248	64	3	72	24	800	26	58
2000/2001[c]	101	387	4,768	90		129	36	359	2,560	422
2001/2002[c]	82	313	5,003	64	6	106	35	10,614		546
2002/2003[c]	89	396	5,913	66	82	134	62	10,748	64	390
2003/2004[c]	91	124		35	127	115	31	3,700		
2004/2005[c]	46	84		19	81	42	32	3,500		

[a] BMUsestablished in pilot areas; [b]BMUs established for the whole lake, [c]Functional BMUs for the whole lake; *BSN* Beach seines; *GNs* Gillnets; *DNs Dagaa* nets; *NP* Nile Perch, *NT* Nile Tilapia

Table 11.4 Illegal fishing gears recorded in biennial frame surveys in Lake Victoria between 1998 and 2016 (on the Tanzanian side)

Year	Beach Seine	Gillnets <5″	Mosquito nets <10 mm	Katuli	Mono-filaments
1998	826	11,771	8	–	–
2000	999	18,128	3,267	–	–
2002	1,996	25,284	4,830	–	63
2004	1,522	88,239	0	–	5,041
2006	1,592	38,947			
2008	1,665	73,841	753		4,801
2010	1,776	116,661	414		2,905
2012	1,301	24,243	5,185		7,994
2014	2,079	45,162	6,481		22,064
2016	1,956	36,065	10,692		19,383

Source: Fisheries Division Frame Survey 2016

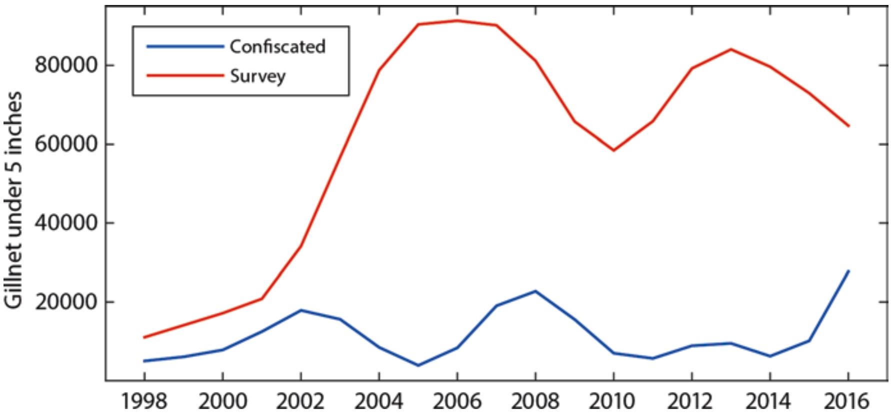

Fig. 11.1 The trend in the number of gillnets (GN) under 5″ confiscated from 1998 to 2016 as compared to biennial frame survey results for the same period

Immature Nile Perch Confiscated in Relation to Under-Sized Mesh Gillnets
There was a corresponding growing trend between the amount of immature Nile perch confiscated and the number of under-sized mesh gillnets confiscated from 1998–2003 (Fig. 11.5). Immature Nile perch were also caught in beach seines.

11.3 Discussion

Before independence, local communities managed the fisheries by themselves through their own clan and kingship systems (Kateka 2010). After independence, the management system changed hands from the local communities to the Central Government until about a decade and a half ago when co-management was adopted.

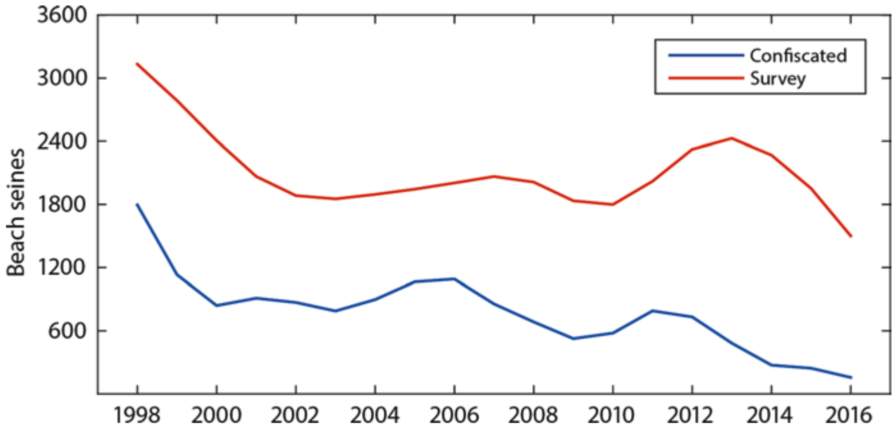

Fig. 11.2 The trend in Beach seines (BSN) confiscated from 1998 to 2016 as compared to biennial frame survey results for the same period

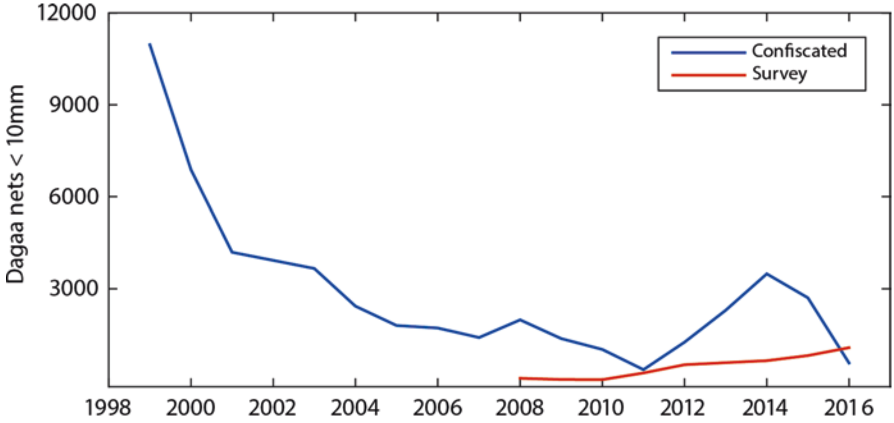

Fig. 11.3 The trend in dagaa nets (DNS <10 mm) confiscated from 1998 to 2016 as compared to biennial frame survey results for the same period

Since then, management of the fish resource including enforcement of the Regulations through conducting of patrols against illegal fishing gears, especially beach seines, under-sized mesh gillnets and dagaa nets of less than 10 mm, is supposed to be done collaboratively between the government and the local fisheries BMUs. The patrols, which were conducted through co-management from 1998 to 2005, had different effects on each type of fishing gear. The reasons for this result are discussed under each gear type.

Under-Sized Mesh Gillnets

The number of gears confiscated increased gradually from 1998 to 2002 and in the following years the number dropped (Fig. 11.1). However, in 2007 the gillnets

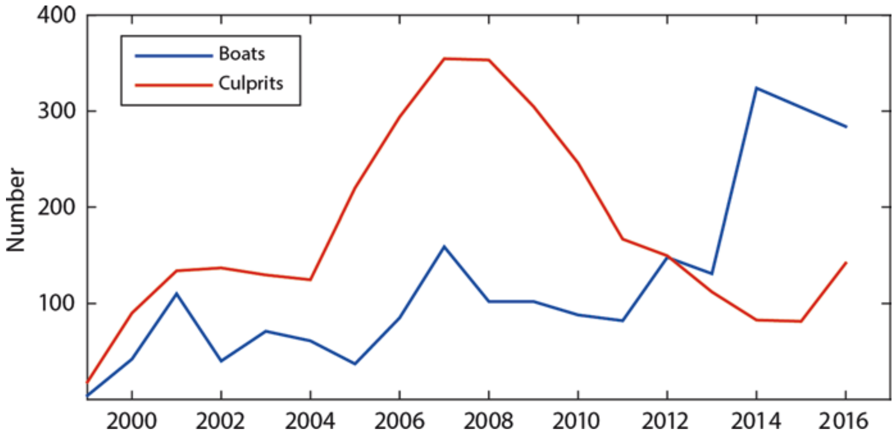

Fig. 11.4 The trend in the culprits apprehended from 1999 to 2016 as compared to the number of confiscated boats in the same period

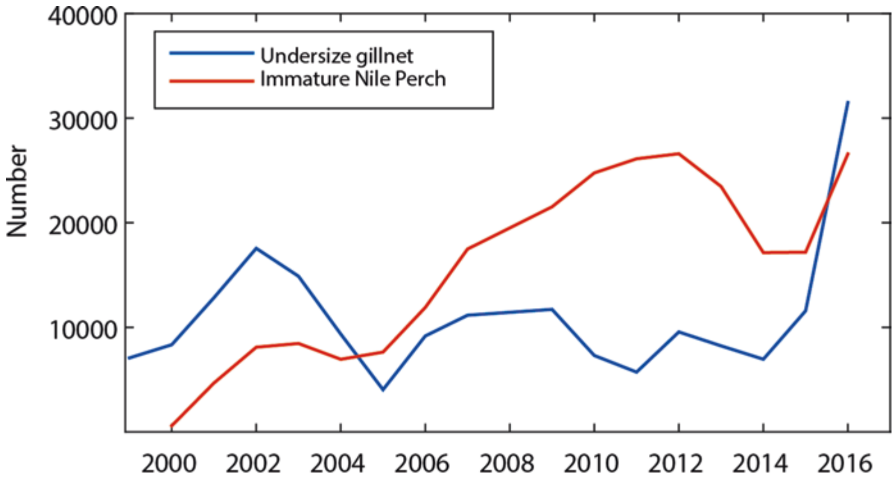

Fig. 11.5 Trend of immature Nile perch (NP) confiscated, 1999 to 2016 in relation to number of gillnets (GN) confiscated

confiscated were the highest and then it dropped again to its lowest level by 2015 but increased in 2016 (URT 2017). In the first 2 years (1998–2000) the contribution by the BMUs was not very substantial because this was the time when the BMUs were being established around the lake. In the 2 years that followed (2001–2003), a substantial amount of this gear was confiscated (Fig. 11.1).

Thereafter the number decreased by about six times from 20,623 units of gear confiscated in 2002 to 3,625 in 2004 and 3,853 in 2005. The decline in the amount of gear confiscated may be attributed to the decreased support from LVEMP I. It was at this time that the first phase of the project was ending. The project enabled

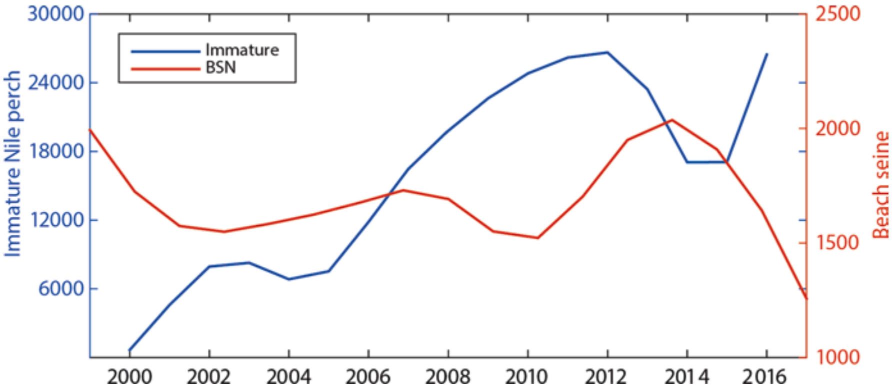

Fig. 11.6 The trend in the immature Nile perch (NP) confiscated from 1999–2016 in relation to the number of beach seines (BSN) confiscated

district fisheries officers to conduct frequent patrols and follow-ups on the BMUs. In a situation of limited funding, patrols and follow-ups on the BMUs were limited with low results.

Beach Seines

There was a declining trend in the number of confiscated beach seines from 1999 to 2005 (Fig. 11.2). The largest number was confiscated in 1998 (2,395 beach seines) and this number decreased by about 3 times in 2004, indicating that the patrols, which were being conducted against this gear, were not yielding good results. The levels of confiscation have remained high at over 1000 seines even in 2016 (see URT 2017). The biennial frame survey results for 2000, 2002 and 2004 (Fig. 11.2) indicate that beach seines were increasing. This is an indication that fishermen were increasingly using this gear.

There are reasons why this is happening. Beach seines have good returns in shorter times than other fishing gears. The fine (Tsh 300,000) is not deterrent enough to make fishermen stop using this gear. In addition, fishermen easily avoid being caught because they are normally warned beforehand of an approaching patrol unit by their colleagues through mobile phones, which are now possessed by most fishermen. Lastly, some of the owners have social influence in the fishing communities, so much so that the BMUs shy away from apprehending such people.

Dagaa Nets of Mesh Size Less Than 10 mm

While the number of dagaa nets with mesh sizes less than 10 mm in possession by fishermen (according to frame surveys) was increasing, the number of confiscated dagaa nets was declining (Fig. 11.3). The exceptionally high number of confiscated nets in the year 2001 may be attributed to a special operation against piracy conducted on the lake in that year.

Dagaa nets are used in open water and catch only one type of fish, *R. argentea* (silver cyprinid or dagaa). The community feels that the gear does not harm the stocks and the environment and therefore they give it no priority. Worse still, the riparian states (Kenya, Tanzania and Uganda) have not agreed yet on the right mesh size to be used in the lake. These circumstances have influenced the BMUs to the extent that they ineffectively enforce the regulations on dagaa nets, except when they are working with the respective Government surveillance units.

11.3.1 Priorities in the Fisheries Sector

Fishery resources are important natural resources. These resources, as pointed out earlier, contribute immensely to the supply of food, employment for the people, and generate a substantial income for the riparian communities and the Government, which earns foreign exchange from exported fishery products. In order to properly manage the resources, the Ministry has put in place a Sector Policy, a policy in which priorities are embodied. Furthermore, there is a Fisheries Act No. 22 of 2003 and Fisheries Regulations of 2009, which accommodate most of the challenges and recent developments in the fishing industry.

The Policy's overall goal is to promote the conservation, development and sustainable management of fishery resources for the benefit of the present and future generations. There are 13 main areas to which development efforts are directed (United Republic of Tanzania (URT) 2015). The areas are:

- Improved resources management and control: The government would efficiently use the available resources to increase fish production so as to improve fish availability as well as contributing to the growth of the economy.
- Improved training and education: The government would assess the training needs in the sector and optimally use national and international institutions on the basis of the needs.
- Improved knowledge of the fishery resource base: The government would enhance knowledge of the fishery resource base.
- Efficient utilization and marketing: The Government would improve utilization of fishery products and marketing thereof.
- Applied/strategic research: The Government would promote research programmes, which are responsive to the fisheries sector.
- Aquaculture development: The Government would promote small scale and semi-intensive aquaculture systems with simple technologies, low capital investment, and sound utilization of the ecological capacity of water based areas to diversify incomes and diets.
- Community participation: The Government would improve involvement of local communities in planning, development and management of the fishery resources.

For each of the above areas there is a set of strategies, which would be implemented to achieve the desired outcomes.

11.4 Conclusion

The fishing communities in the three riparian regions have seen a decline in the indigenous fish species, including the decline in the most important commercial fish species, *Lates niloticus,* due to the increased use of illegal fishing gear and practices, and possibly environmental changes. If these practices are allowed to continue, the end-result will be the loss of socio-economic gains by the stakeholders and the nation as a whole.

The involvement of the fishing communities in the management of the resources through the establishment of BMUs has created a forum for exchange of ideas, knowledge and experience on the resources. This strategy has made the communities understand the importance of compliance to the law and regulations and effective management measures. Awareness on the importance of sustaining the resources is more evident now among the fishing communities than before LVEMP was established. The number of patrols carried out and illegal fishing gears confiscated by BMUs alone bears this out.

The Government replaced the Fisheries Act of 1970 with the Fisheries Act of 2003 in order to incorporate effective management tools like co-management and surveillance units. These developments have had a positive impact on the management of the resources. Today, fishermen/the BMUs are carrying out patrols in collaboration with fisheries staff. There is effective monitoring, control and surveillance in all the aspects of fisheries management. However, the remaining challenge is to adequately support the BMUs because they have inadequate financial resources and poor working tools. In addition, more awareness and education on the environment, conservation and development of the resources is required to enhance the combating of illegal fishing practices.

11.5 Recommendations

With respect to the Lake Victorian fisheries sector, BMU involvement and participation in management is critical. If the resources are to be protected, conserved and sustainably harvested, every effort has to be made to ensure that they are always at zeal to manage the fisheries resource. The following measures are recommended:

- The District Officers assigned with the job of monitoring of BMUs should rementor them, especially on the implementation of Fisheries Management.
- The strategies of combating illegal fishing should be jointly worked out by Ward Fisheries Officers (WFOs), Village Government Officials and the BMUs.
- There should be deliberate plans by the WFOs and District Fisheries Officers to lobby the District Tender Authority to contract BMUs to collect revenues instead of individuals, as it is presently the case. This would enhance their financial capacity.
- The local Governments should support BMUs materially and financially to boost their morale and capacity to perform their responsibilities.

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Chapter 12
Fisheries Statistics for Lake Victoria, Tanzania

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Abstract Time series fisheries statistics data mainly from Frame Surveys, Catch Assessment Surveys and Fisheries Annual Statistics Reports for Lake Victoria from 1967–2016 were collected from the Fisheries Development Division in Tanzania. These surveys and reports comprised relevant information and data on fish catches and fishing effort. The data were analysed and used to describe variations and trends in the number of fishers, number of fishing crafts, fish weight, catch per boat, total number of gillnets, beach seines, longline hooks, outboard and inboard engines. Frame Survey results showed an increasing trend in the number of fishers and fishing crafts, with the highest number of fishers and fishing crafts being 109,397 and 31,773, respectively in 2016. Longline hooks increased from 2,200,901 in 2000 to 8,163,119 hooks in 2016. In general, the catch per unit effort (CPUE) for all species was high at 39 mt/boat/year in 1967 and decreased to 8 mt/boat/year in 2014. However, CPUE for *Lates niloticus* has increased since the late 1980s, with the highest CPUE of 19.22 mt/boat/year being recorded in 1995, and from 2000 it decreased gradually to 7 mt/boat/year in 2014. As the fisheries statistics show an increase in fishing pressure over the years, it is evident that there is a sign of overfishing. For that matter, effective fisheries management is needed for the three riparian states to safeguard the sustainable use of fishery resources in the lake and to provide data that can be used in the evaluation of the fisheries objectives.

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12.1 Introduction

The fishery resources of Lake Victoria have been monitored since the 1950s (East Africa High Commission 1953) and fisheries catch records have been kept since 1959. The catches of various species are known with a considerable degree of accuracy (Fisheries Development Division 1966). Fish production was estimated from the amount of fish caught and its effort, while the fishing inputs like fishing crafts, fishing gears and fishers were enumerated. However, the process and methods of how to estimate catches of various species from the amount of fish caught were not elaborate at that time (Fisheries Development Division 1966) simply because there were few landing sites and catches were enumerated to get a total.

Initially, the East African Freshwater Fisheries Research Organization devoted a considerable amount of effort to analyzing fisheries records of the fish caught in Lake Victoria (East Africa High Commission 1959). The organisation assessed the trends in various fisheries and fluctuations of fishing effort. The Ministry responsible for fisheries was given the mandate to produce annual fisheries statistical reports following the establishment of the Fisheries Development Division in 1965. However, data collection and processing procedures were not standardised through the 1960s to 1980s. In the 1990s, Food and Agriculture Organisation (FAO) of the United Nations came up with a standardised estimation process of using Frame Surveys and sample surveys of catch and effort data from daily catches and related efforts.

The Fisheries Development Division maintains a statistical data collection and processing unit, which has evolved in four phases from 1970 as a manual process, which was computerised in 1989, improved in 1993 and updated into a database from 2001. The four phases are based on a sampling method, which uses baseline data from annual Frame Surveys. Sampling for the first two phases involved a random sampling of 16 days per month, per sampling site, involving as many crafts as possible, whereas in the new phase, sampling is done for 10 days which are randomly selected. This sampling involves boat - gear combination of 3 samples for each gear per day, which makes 30 samples of each gear per month. The advantage of the new system is that it can reduce cost of data collection, thus reducing errors in the estimation process.

Fisheries statistics are important in the management of fishery resources. The information obtained from fishing inputs and outputs is used in the short- and long-term management plans. In this sense, fisheries statistics must be collected, analysed and managed. It is essential that the most appropriate and accurate information for the management of fisheries be continuously collected, processed and provided in a timely manner for effective management. Reliable and accurate information is crucial because only well-informed decision makers can make good decisions.

Fisheries statistics on Lake Victoria are important because they show the behaviour of the different exploited fish species. The data can tell, whether the fishery is at an optimal or critical point. Furthermore, the data can provide market information, fishing effort and the presence or absence of illegal fishing gear, among other things (Fisheries Division 2005). The fisheries data collected from Lake Victoria are used in the management of the resources and for commercial and scientific purposes. The data show the exploited fish and associated species, as well as economic information about the fishers and the market of catches (Fisheries Division 1967, 1968, 1969). Some of the data, which are being collected in Lake Victoria include Frame Surveys, catch assessment surveys and export information.

12.1.1 Frame Surveys

Frame Surveys are census to provide information on social amenities, facilities and services at the landing sites, the composition, magnitude and distribution of fishing effort to guide development and management of the fishery. Data collected include the number of fishers, the number of fishing crafts and gear by type and size. They also provide a description of fishing and landing activity patterns, processing and marketing patterns as well as a description of supply centres of goods and services (FAO 1998). The main objectives of the surveys are:

- To secure data on the current fishing effort (i.e. the number of fishers, the number of fishing crafts, the number of fishing gear by type and size) and socio-economic information on the available facilities and infrastructure at the landing beaches;
- To provide a raising factor for the estimation of fish caught when data are collected on a sampling basis, i.e. to get estimation on fish production;
- To provide sampling frames for various surveys being conducted and those to be conducted in the future; and
- To provide data that can be used for the estimation of fish stocks (stock assessment).

Before the 1960s, the surveys were not conducted; however, the number of fishers and fishing gears were reported as part of fisheries statistics recorded at the fish landing beaches (Fisheries Development Division 1967). After the establishment of the Fisheries Development Division in 1965, surveys were conducted on an annual basis from 1967 to 1999 and then biennially from 2000 to 2016 by using the fisheries staff. Due to the expansion of fisheries activities in Tanzania, the Division decided to conduct Frame Surveys biennially from 1992. However, the surveys were sometimes delayed by lack of funds and logistical problems. Hence, they were not conducted from 1992 to 1995 and from 1995 to 1998. In 2000, the riparian states sharing Lake Victoria, under the Lake Victoria Environmental Management Project Phase I (LVEMP I) and the Lake Victoria Fisheries Organisation (LVFO), agreed to conduct harmonised Frame Surveys concurrently in the three Riparian States. The three Riparian States agreed to continue carrying out harmonised Frame Surveys so as to avoid double counting of the fishers and other effort groups as they occasionally move from one landing site to another and sometimes even across to another country.

12.1.2 Catch Assessment Surveys (CAS)

The recorded history of Lake Victoria fisheries starts in the early years of the nineteenth century (East African Common Services Organisation, EACSO 1967). Historical data retrieved from Lake Victoria Fisheries Service annual reports show that by 1953, catch assessment surveys had been carried out in all fish landing sites lake-wide (East Africa High Commission 1958). The data were recorded in data sheets in terms of fish species, the number of fish (in pieces) caught, the number of fishers and crafts. During the post-independence period, fisheries management activities were placed under the Ministry of Agriculture, Forests and Wildlife and a Lake Region Fisheries officer was given the task of preparing annual statistical reports for the Tanzanian part of Lake Victoria. From 1986 to 2014, the catch assessment survey data were collected only at the selected landing beaches and analysed centrally using computers at the Fisheries headquarters in Dar es Salaam. The data were collected for the whole month and it involved as many crafts as possible. The collected data were extrapolated with the number of fishing crafts by gear type (from Frame Survey data) to get the estimated total catch. This methodology continued during the life of LVEMP I and II where CAS data were collected only at designated landing sites. In 2005, during the Implementation of Fisheries Management Project (IFMP), fisheries data were collected by involving Beach Management Units (BMUs), which were assigned to perform such activities as one of their roles and responsibilities in the implementation of Fisheries policy and legislation. The BMUs were paid by the project as a way of encouraging them to perform such activities and as an incentive to them. However, after the end of IFMP, since the government had no funds to pay BMUs, it became difficult to get fisheries data. Currently, most of the district authorities have tried to employ their fisheries staff who are expected to collect data at their respective landing sites.

12.2 Results

12.2.1 Frame Surveys

The results of fisheries Frame Surveys from 1967 to 2016 are presented in Fig. 12.1. Generally, fishing effort has been increasing despite the declining fish stocks in the lake. Fishers and fishing crafts have both increased over the years from 6077 fishers in 1967 to 109,397 fishers in 2016 and fishing crafts from 1289 in 1967 to 31,773 in 2016. The major fishing gears, namely, gillnets and longline hooks have been equally increasing over the years. Gillnets increased from 73,037 in 1967 to 361,235 nets in 2016; longline hooks from 138,702 in 1967 to 8,163,119 hooks in 2016. Fishing crafts propelled by outboard engines have been increasing from 1451 in 2000 to 11,083 in 2016.

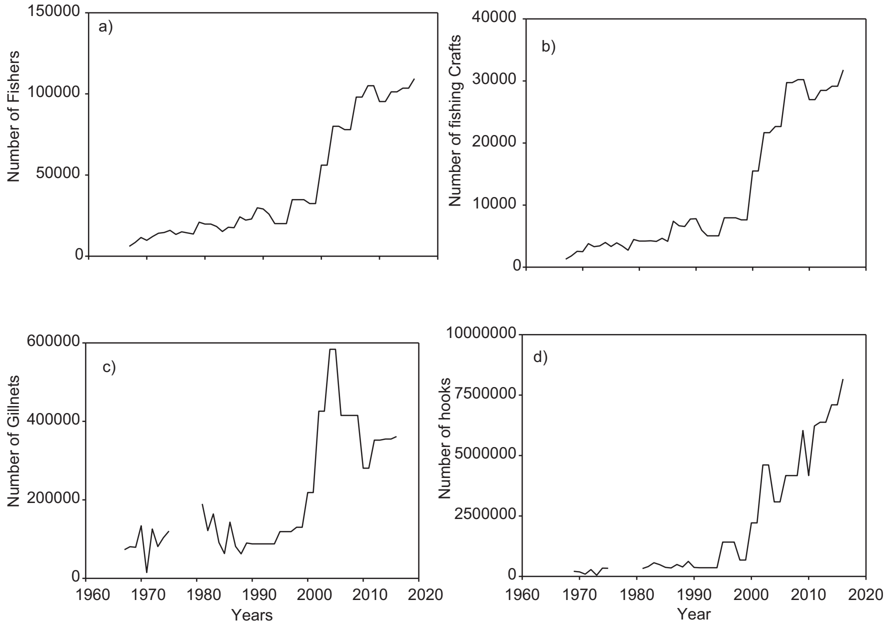

Fig. 12.1 Lake Victoria fishing effort for 1967–2016 showing (**a**) number of fishers (**b**) number of fishing crafts (**c**) total gillnets and (**d**) Longline hooks (Data from Fisheries Division Statistics)

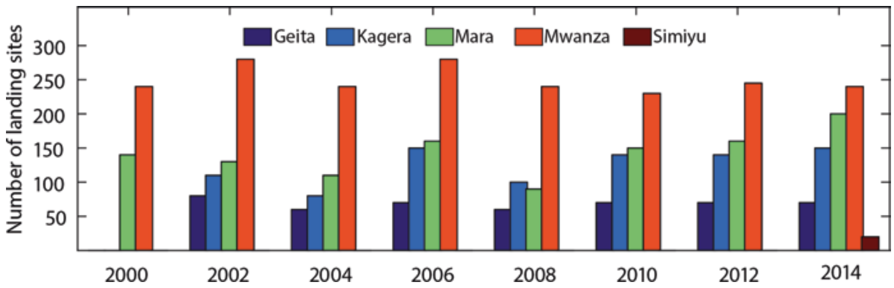

Fig. 12.2 Landing sites by regions (Data from Fisheries Division Statistics)

12.2.2 Fishing Effort for Regions Bordering Lake Victoria

Results for the joint Frame Surveys conducted in 2000, 2002, 2004, 2008, 2010, 2012, 2014 and 2016 indicated that, in general, the number of landing sites and number of fishers increased. Kagera region recorded the highest increase in number of landing sites (24) whereas Mwanza region indicated a decrease in number of landing sites by 20 (Fig. 12.2). When the results of the 2014 and 2016 Frame Surveys are compared, the number of fishers in Mwanza and Kagera regions increased, whereby Mwanza registered an increase of 5.24% fishers and Kagera

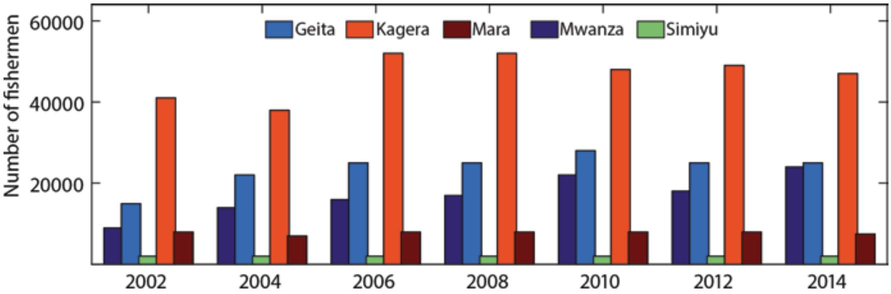

Fig. 12.3 Fishers by regions (Data from Fisheries Division Statistics)

7.45%. Although Simiyu Region had the smallest fisher population, it recorded the highest rate (8.8%) of increase in number of fishers (4000 in 2014 to 4386 in 2016). In Geita the number of fishers increased by 3.46% and Mara by 3.64% (Fig. 12.3).

According to Frame Survey results obtained in 2016, more than half of the fishing crafts are propelled by paddles (18,389 crafts), representing 57.9% of all crafts recorded in this survey. The number of paddled crafts increased by 5.3% from 17,461 recorded in the 2014 survey to 18,389 crafts in 2016. The second most dominant means of propulsion was outboard engines used by 11,093 crafts (34.8%). Crafts propelled by sails constituted 2266 crafts (7%) while towed crafts were 28 (0.2%) in 2016. However, fishing crafts using sails have decreased by 17 (0.8%) from 2249 crafts reported in the 2014 to 2266 crafts in the 2016 survey. Towed fishing crafts increased from 28 recorded in 2014 to 52 crafts in the 2016 survey.

12.2.3 Catch Assessment Surveys

Catch data are an important indicator for assessing overall production from both the biological as well as the national economic point of view. Overall, fishing effort measured by the number of fishers, boats and gears, is the single most important measure of fishing pressure on stocks. Effort indicators are also highly useful as economic indicators for assessing both the movements of labour into and out of the fishery (van Zwieten et al. 2003a) and in the assessment of the level of investment in the fishery (van Zwieten et al. 2003b).

Figure 12.4 shows the estimated fish production of Lake Victoria from 1959–2014. Before 1997, the observed data were reliable and accurate since the collection and analysis of the data at the Fisheries Development Division was adequate. The data from 1997–2004 consist of estimates, which might not be accurate since there were no enumerators to collect fisheries data. Data from 2005 to 2014 are reliable since there was improvement in data collection system and databases.

Catches per unit effort (CPUE) of the most important species, i.e. *L. niloticus,* haplochromines*, Clarias* spp.*, Rastrineobola argentea* and the four indigenous spe-

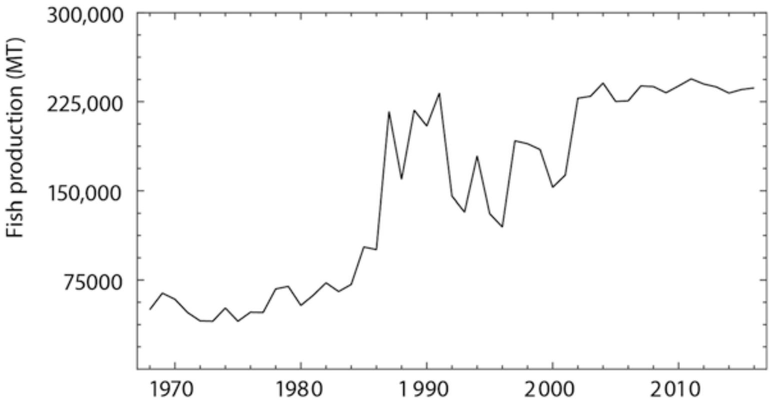

Fig. 12.4 Lake Victoria fish production from 1959 to 2014 (Data from Fisheries Division Statistics)

cies of tilapia were calculated in relation to the number of fishing crafts available (Fig. 12.5). The CPUE of *L. niloticus* has increased since the late 1980s and reached a peak at 19.22 mt in 1995 as a result of the intensified export of Nile perch fillets. From 2000 to 2014 the CPUE decreased gradually to 7 mt/boat/year, showing a decline in stock sizes. The CPUE of haplochromines increased slightly from 6.3 in 1970 to 9.9 mt/boat/year in 1975 and decreased to 0.1 mt/boat/year in 1995. This decline might be attributed to heavy predation by the Nile perch (Bwathondi 1987) and environmental degradation. In a recent assessment, the catch for dagaa had the highest CPUE at 14 mt/boat/year, Nile perch at 11 mt/boat/year, haplochromines 8 mt/boat/year, tilapiines 6 mt/boat/year, *Clarias* spp., *Protopterus* spp., *Bagrus* spp. and other fish species combined together contributed 0.9 mt/boat/year. All tilapia species declined from the 1970s to the 1990s, with the exception of *Oreochromis niloticus*, which peaked in 1985, decreased slightly in the 1990s and increased to 2.0 mt/boat/year in 2000. Overall, CPUE (measured as tonnes/boat/year) fluctuated over the years (1967–2014) with no discernible trend (Fig. 12.6).

12.2.4 Initiatives in Data Collection and Processing

One of the objectives for the establishment of the Lake Victoria Fisheries Organisation (LVFO) is to "serve as a clearing house and data bank for information on Lake Victoria fisheries and to promote the dissemination of information, without prejudice to industrial property rights, by any appropriate form of publication" (LVFO 2001). A regional working group has been established with support from the European Union (EU) for funding the Implementation of Fisheries Management Plan project. The group is comprised of members from the Fisheries Development Division headquarters, fisheries research institutions and a few district fisheries

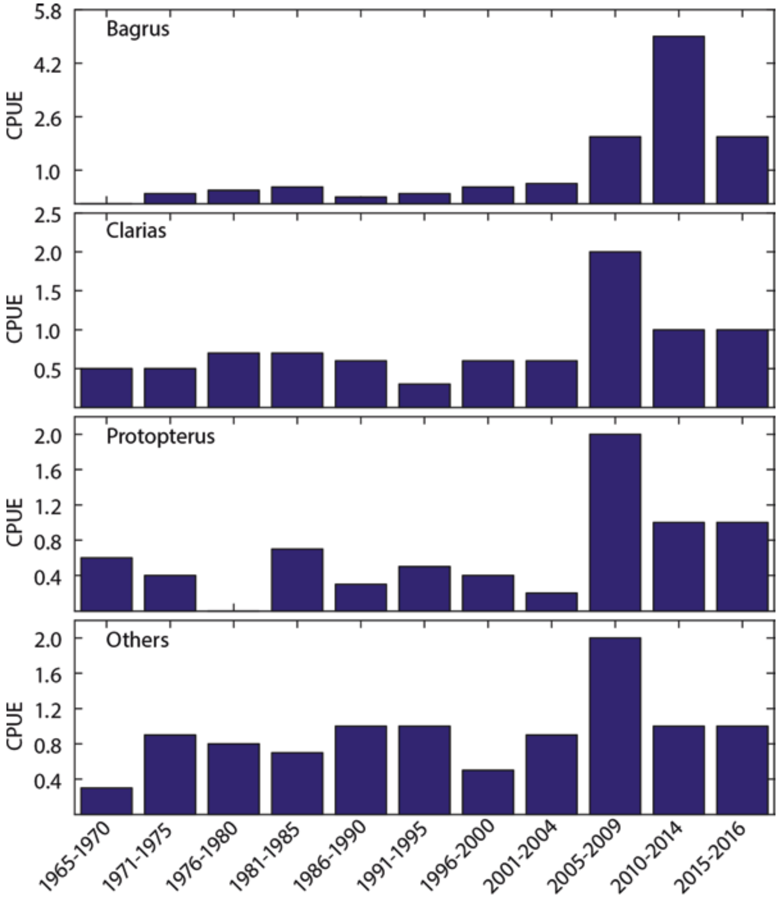

Fig. 12.5 Catch per unit effort, CPUE (catch (tonnes)/boat/year) of the most important species in Lake Victoria from 1965 to 2016. These species included Nile perch, Tilapiines (*Oreochromis variabilis, Tilapia zillii, O. esculentus*, and *O. niloticus*), *R. argentea*, Haplochromines [top figure], *Bagrus* spp., *Clarias* spp., *Protopterus* spp. and Others [bottom figure] (Data from Fisheries Division Statistics)

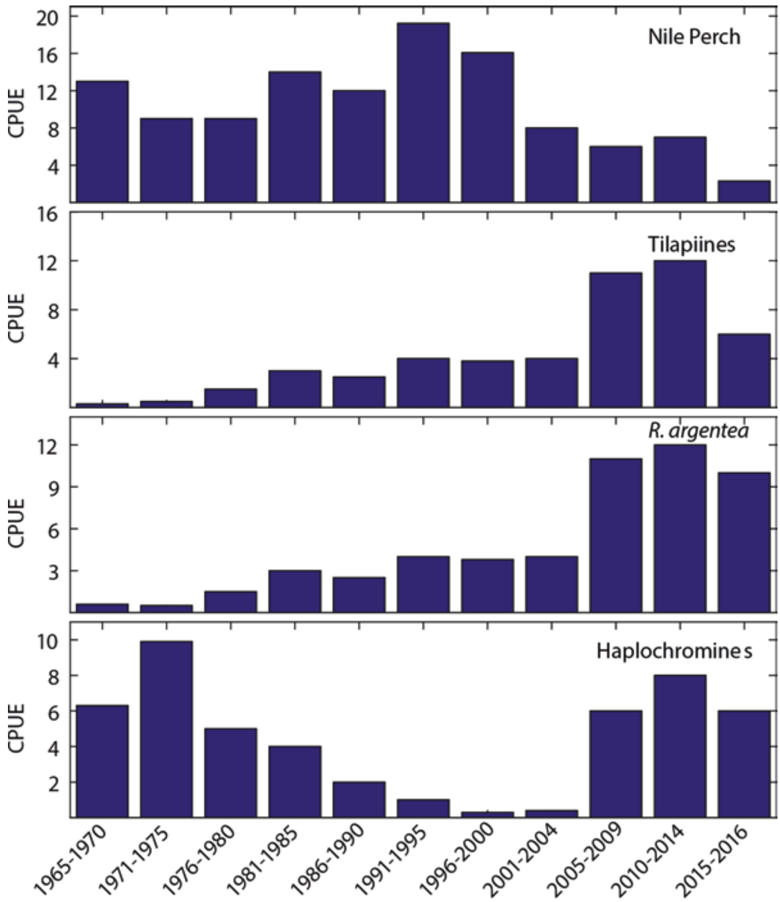

Fig. 12.5 (continued)

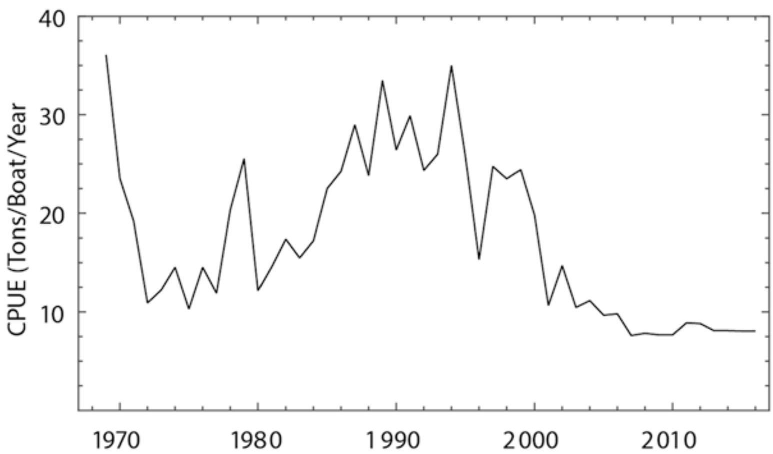

Fig. 12.6 Catch per unit effort, CPUE (catch/boat/year) for Tanzania from 1967 to 2014 (Data from Fisheries Division Statistics)

officers based in the regions bordering Lake Victoria. The group developed Standard Operating Procedures (SOPs) for Catch Assessment Surveys. Surveys for sampling sites had already been conducted based on randomly selected landing sites. However, sampling is sometimes systematically done as it depends on the accessibility of the landing site and the availability of the fisheries' staff at the landing sites or the presence of active beach management unit members. The collected information includes the weight and value of fish by species and by boat and gear type in terms of size.

12.3 Discussion

12.3.1 Frame Survey Data

Generally, Lake Victoria fishing effort increased from 1965 to 1991 (Fig. 12.1). In 1992, there was a decrease in fishing effort, which could be explained by the fact that the Tanzania government imposed a ban on the export of whole fish to Uganda and Kenya during the period of 1992–1993. However, from 1995, the effort in terms of fishers and crafts increased by 73% and 57%, respectively, presumably as a result of the growth in the export of the Nile perch.

The East African Community (EAC) Partner States (Kenya, Tanzania and Uganda) conducted Frame Surveys on Lake Victoria individually since the 1970s at the country level. However, from 2000, the LVFO Secretariat has been coordinating Lake-wide Frame Surveys and concurrently the surveys were conducted in a harmonized manner using standardized data capture form. These Frame Surveys conducted in 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2014 and 2016 showed a rapid increase in the number of fishing crafts and fishers on the Tanzanian side of Lake Victoria compared to the previous years (Fig. 12.1). This is likely due to better coverage during the joint surveys, which usually cover the whole shoreline of Tanzania from the border with Kenya on the eastern part of the lake to the border with Uganda on the western part of the lake (including the islands).

Generally, the increase in the number of fishers is closely related to the number of fishing crafts in Lake Victoria. In most cases, the fishing crafts available in Lake Victoria do not take more than 5 fishers at a time. Thus, the results reported here are not surprising.

The data on fishing gear indicate that gillnets with 5″ mesh size are very popular. They increased from 15,160 in 1995 to 272,224 in 2004. Recent surveys of 2014 and 2016 revealed that, there is an increase in the use of gillnets with bigger mesh sizes compared to those with smaller mesh sizes. This is due to the fact that, from 1996 the "Retention Scheme" started to be implemented, whereby district authorities were given money from the Fisheries Development Fund for fisheries development activities. In most cases, surveillance has always been well-funded, resulting in greater compliance. However, beach seines seem to increase although the government prohibits their use. The non-compliance is probably driven by higher catch rates by the gear, hence bigger profits, but it could also be the result of very low fines for the culprits, i.e. TZS 300,000/= or the relatively short 3-year jail sentence.

12.3.2 Catch Assessment Surveys

Catch per unit effort fluctuated with time (Fig. 12.5). The observed catch per boat reached 39 mt/boat/year in 1967. This could be explained by the fact that during that time fewer fishers accessed the lake and fish stock levels were high. As the years went by, more fishers entered the fishery, thus the CPUE dropped to 11 mt/boat/year in 1972. However, with the advent of the Nile perch, the CPUE rose again to 29 mt/boat/year in 1987 reaching 34.97 mt/boat/year in 1993. The CPUE began to fluctuate again in 1998 and it reached an average of 8 mt/boat/year in 2010, 2012 and 2014.

The fish catches in Lake Victoria had been fluctuating up to 1986, whereby more than 57% of the catch was Nile perch. In 1987, the CPUE of haplochromines decreased dramatically while that of the Nile perch increased steadily up to the period of 1996–2000 (Fig. 12.5). Catch assessment processes collapsed in 1997; consequently, the provisional data that have been reported since 1997 cannot be used to conclude that the observed decline in fish catches from 1998–2002 is a direct result of high fishing effort or the decline in fish stocks. However, the possibility that there is a general decline in stocks in the lake cannot be ruled out because of insufficient data.

The Fisheries Development Division has made some efforts towards improvement of the reliability of Lake Victoria fisheries statistics. In 2000, there was some training at the district level on data collection and processing. The LVFO introduced SAMAKI, the East African Fisheries database for Frame Surveys, Catch Assessment analysis and all related information concerning fisheries statistics for the whole of Lake Victoria. The database was installed in Mwanza, Mara and at the Fisheries Division headquarters' computers. However, this database has not been used at the district level in Mwanza and Mara due to lack of capacity (personnel and technology). Consequently, the data are centrally analyzed at the headquarters in Dar es Salaam.

The reasons that led to the collapse of collection and analysis of fisheries statistics include the following:

- Most of the data enumerators were retrenched at the district level, and the few who remained were mobilized for revenue collection by the district authorities.
- The Tanzania Fishery Information System (TANFIS) software introduced by FAO in 1993 so as to improve data analysis was incompatible with the new MS Windows and the computers used were broken. In addition, the computers were not repaired due to lack of funds at the Fisheries Division.

- The project "*Strengthening Fisheries Statistics*" was over by then and there were no funds to cover the collection of fisheries statistics in Tanzania.
- Inadequate human resource capacity (data analysts and programmers) at the Fisheries Division head office, as the Division has only 4 members of staff at the Statistics Unit.

12.4 Conclusion

Since 1967, numerous changes have taken place in the Lake Victoria fisheries. The biennial fisheries Frame Surveys carried out on Lake Victoria from 2000 to 2016, present trends in the number of fishers, crafts and how fishing effort and capacity have changed over the years for proper planning and management. Over the last 40 years, Lake Victoria fisheries' statistical trends showed an increasing fishing pressure and a tremendous decrease in CPUE. This could be a sign of overfishing. For that matter, the newly established BMUs have to be knowledgeable and empowered to participate in fisheries data collection as one of their roles in management of the fishery resources. An effective fisheries statistical programme is crucial to safeguard the sustainable use of fishery resources in the lake and for providing data that can be used in the evaluation of the fisheries objectives.

12.5 Recommendations

- The Fisheries Development Division as the custodian of fisheries statistics in Tanzania should put in place mechanisms for improving data collection, analysis and management so that reliable and accurate information is available in a timely manner. The catch assessment and Frame Surveys generate valuable information on the status of the fisheries in Lake Victoria, hence, biennial Frame Surveys should continue. This recommendation is justified by the fact that the fishery is dynamic and changing rapidly with respect to the total number of fishers and the number and types of fishing gears in operation. It was suggested earlier that the government could use fishers and BMU members in data collection since the exercise requires enough manpower at the source. Community participation in data collection will enhance a feeling of "ownership" of the fishery resources among members of the local communities and motivate them to implement conservation measures. This may be seen as the first step in preparing the communities to play their part in a community-based approach in the management of the resources in Lake Victoria.
- Capacity building in database design, implementation and management should be considered for those who are working in the Fisheries Development Division, especially those in the Statistics Unit. As the East African Fisheries database is already in place, there is a need for the Division to train all those working in

fisheries statistics on how to use it. In addition, computers and accessories should also be provided at the district level to enable the capture and transmission of data to the central place (Statistics Unit).

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Chapter 13
Fish Quality Assurance

S.A. Lukanga and Yunus D. Mgaya

Abstract Lake Victoria fishery resources are of great socio-economic, nutritional and food security significance to over 30 million people in the region, and to the international community. The proliferation of Nile perch in the 1990s increased the dynamics in the fisheries sector as people moved from the hinterlands to the Lake region to engage in Nile perch processing. This has also attracted global and domestic concerns and as a result, has revolutionized fish quality assurance practices around Lake Victoria. Consequently, there was a need to enforce quality assurance measures and increase public awareness on fish quality assurance issues in accordance with the relevant national laws and regulations. To conform to the export market standards, the government adopted the Hazard Analysis Critical Control Point (HACCP) programme, and implemented the Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and Good Laboratory Practices (GLP) measures. It facilitated a mechanism that ensured the overall improvement of the quality assurance chain such as instituting traceability chains, the construction of and equipping the national fish laboratory and conducting regular monitoring and analysis of microbiological and chemical parameters in fish, water and sediments. Fishers and other stakeholders were trained in sanitation and hygiene to ensure that the fish and fishery products are of the highest quality and safe for human consumption. This resulted into an increase in fish exports and significant reduction of Nile perch post-harvest losses, as can be evidenced from the national fishery statistics for the period 1986–2011. As a result, customers are satisfied with compliance in fish quality control and safety assurance measures or programmes in place.

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13.1 Introduction

Lake Victoria fishery resources are of great socio-economic, nutritional and food security significance to over 30 million people in the region as well as to the international community. Fish has for the last 20 years become a major export commodity in the region and has made the riparian governments as well as other stakeholders realise that it is a socio-economic asset, which must be sustainably managed.

Prior to the establishment of Nile perch processing plants in the Lake Victoria zone, the major processing methods were artisanal fish smoking, salting and sun-drying. These methods were used to increase the shelf life of the final product due to the fact that poor rural roads and distribution facilities prevented the distribution of both fresh and processed fish to distant domestic markets. However, the quality of the final product was poor due to lack of ice for lowering temperature soon after the fish are caught. The commercial or industrial processing methods started in the early 1990s for the purpose of producing mainly Nile perch fillets for export to international markets (Europe, Japan, the Middle East and Australia). Apart from fillets, there are by-products like fish frames/carcass, off-cuts, belly flaps and fish maws. These are either sun-dried or salted for export to Rwanda, Burundi and the Democratic Republic of Congo.

There are 10 operational fish processing plants on the Tanzanian side of Lake Victoria and all of them have adopted the implementation of the Hazard Analysis and Critical Control Points (HACCP) programme. The total cumulative exports of the Nile perch and others from Lake Victoria for the last 20 years (1995 to 2015) was 750,341 tonnes valued at USD 2,402,814,420.31 (free on board, F.O.B. value), of which the Fisheries Development Division received a total of Tsh 104.26 billion (US$ 88.19 million) as royalty.

Since the major proportion of the catch (about 90% of the Nile perch) is processed in fish factories for international markets, dagaa (*Rastrineobola argentea*), tilapiines and other species are locally processed for both human and animal consumption. For example, dagaa are sun-dried for both human and animal consumption, depending on the quality of the raw materials and final products, while tilapia are gutted and washed for consumption in towns where individual dealers freeze them for local markets in Arusha, Dar es Salaam and Dodoma.

The Nile perch, as both food and wealth, has attracted global and domestic concerns. European Union countries enforced the provisions of Regulation (EC) No. 852/2004, No. 853/2004, and No. 854/2004 with intermittent audit/inspection missions, which have revolutionized fish quality assurance practices around Lake Victoria. At the same time, Tanzania has revolutionized industrial fish processing by increasing public awareness on fish quality assurance issues. According to the Fisheries Act No. 22 of 2003, Food Act No. 10 of 1978 and the Fisheries Regulations of 2009, the Fisheries Development Division is the Competent Authority on all issues related to fish quality assurance such as control, fish handling, monitoring of fish establishments, fish marketing and addressing sanitation and hygiene issues.

The need for lake wide compliance with international and customary requirements forced the Fisheries Development Division to provide short and long courses to fish inspectors and laboratory technicians, institute traceability chains, construct and equip a national laboratory and conduct regular monitoring and analysis of microbiological and chemical parameters in fish, water and sediments. Fish traders, Beach Management Unit (BMU) members, fishermen and fish handlers were trained in health sanitation and hygiene. All these are done in order to ensure that our fish and fishery products are of the highest quality and safe for human consumption.

13.2 Results

13.2.1 Export Statistics

In the 1950s, most of the fish from Lake Victoria were consumed in areas very close to the lake because of poor roads and poor distribution facilities, which prevented the distribution of both fresh and processed fish to distant domestic markets. Although there is no export data, the existing records show that fish exports from Lake Victoria were carried out in the 1950s with products like smoked and salted fish being exported to both Kenya and Uganda from various processing camps in Tanzania.

Fishmongers from Kisumu bought fish from Musoma at different times in 1968 (Fisheries Development Division 1968). During that time, exports were in the form of fresh fish, chilled or frozen and dried fishery products. It was shown that, in 1965, the Fisheries Development Division had a plan to establish an Experimental Fish Processing station at Nyegezi in Mwanza with the aim of improving the smoking, drying, salting and processing of fish for local as well as foreign markets (Fisheries Development Division 1965). This was successfully implemented and it contributed immensely to the improvement of the preservation of fish and fishery products.

The importance of the lake with respect to the export of fish and fishery products was realized in the early 1990s when the Nile perch (*Lates niloticus*) started to be processed and exported in the form of fish fillets. This can be economically demonstrated by the amount of fish that was exported and the income generated for the country. The total amount of the Nile perch and its products exported in 2015 was 29,007.8 tonnes, valued at US$ 250,309,406 (F.O.B. value), of which the Fisheries Development Division received US$ 5.67 million as royalty.

Fish and fishery products statistics for the period 1986–2015 are given in Fig. 13.1. It is evident that there was a significant increase in fish exports in terms of quantity per year ($R^2 = 0.49$) as well as value (Fig. 13.2) although from the year 2007, exports decreased by weight while values still increased, probably as a result of market forces (supply and demand). The sudden drop in the amount of fish exported in 1999 and 2002 was due to the import ban imposed by the European market caused by the allegation that our fish and fishery products were contaminated

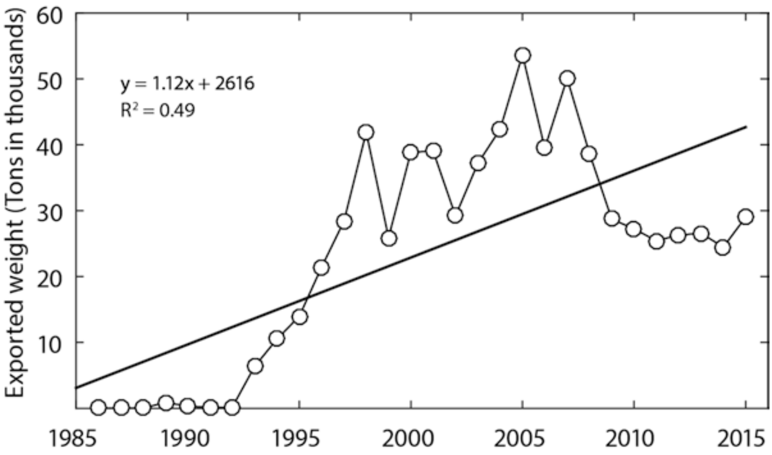

Fig. 13.1 Statistics on the export of fish and fishery products by weight for the period 1986–2015. (Data from Fisheries Division Statistics Reports)

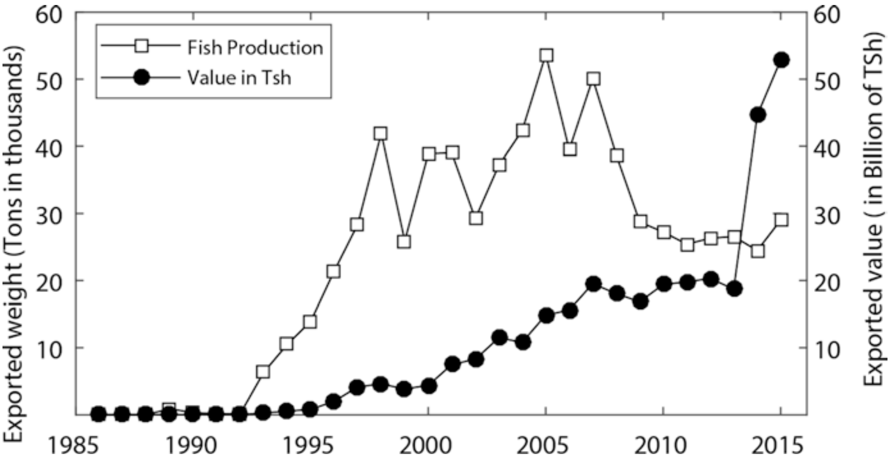

Fig. 13.2 Statistics on the export of fish and fishery products by weight and value for the period of 1986–2015. (Data from Fisheries Division Statistics Reports)

by pesticides as well as the implementation of the slot size of 50–85 cm in the fish processing plants which began in 2002 (Table 13.1).

The Nile perch processing plants are dedicated to the packaging and exporting of fresh, chilled, frozen fillets, whole and gutted fish heads and fish maws. The major part of these products is exported to European countries, the USA, Japan, Australia and the Middle East. Nile perch carcass, dried fish, fish offals, Nile perch chips or off cuts, fish meal, belly flaps, fish skin and fish oil are exported to Burundi, the Democratic Republic of Congo, Rwanda, Kenya, Malawi and Uganda.

Table 13.1 Fish and fishery export statistics from 1986 to 2015

Year	Weight in Kg	FOB value in TShs	FOB value in US$	Royalty in TShs
1986	3990.00	455,104.00	11,325.34	22,754.00
1987	23,546.00	1,693,231.50	42,136.37	69,936.40
1988	29,888.50	2,210,033.69	54,997.09	285,063.65
1989	886,441.00	35,382,680.00	445,086.00	319,184.00
1990	334,885.00	44,374,328.00	237,560.15	1,937,555.00
1991	138,364.00	48,386,346.15	1,318,551.22	1,405,703.50
1992	174,059.00	116,697,374.56	384,480.75	5,871,525.46
1993	6,358,578.00	2,719,443,141.05	3,802,208.25	144,686,154.31
1994	10,505,872.50	5,344,108,936.20	14,779,081.70	278,194,833.70
1995	15,713,340.40	8,366,171,298.61	15,357,360.10	450,084,515.34
1996	22,902,397.53	20,258,644,706.68	53,861,195.29	1,232,281,896.39
1997	29,918,834.00	37,150,631,873.50	61,479,057.80	2,228,968,993.30
1998	42,604,967.93	46,361,735,219.43	70,499,311.55	2,781,704,250.60
1999	26,579,318.40	38,857,009,470.86	53,835,540.67	2,335,974,141.96
2000	39,339,511.18	44,346,051,395.99	55,924,563.03	2,660,694,101.46
2001	39,497,752.20	75,303,371,141.58	86,635,225.20	4,701,153,443.00
2002	28,004,271.01	82,491,602,201.66	87,687,169.29	4,949,496,132.10
2003	37,219,782.36	114,822,828,778.49	112,092,595.58	6,710,533,895.73
2004	42,843,453.82	108,594,851,195.63	100,376,716.16	6,437,000,257.82
2005	54,976,270.89	150,245,342,829.91	130,166,765.62	8,482,189,071.58
2006	40,859,225.77	157,083,788,788.83	127,580,009.54	5,575,827,093.56
2007	53,103,024.60	197,429,324,753.92	160,257,428.06	6,814,907,772.30
2008	46,407,197.22	186,245,776,827.45	158,631,296.42	5,804,153,292.90
2009	29,144,182.90	131,941,975,611.04	102,174,266.09	3,819,574,466.79
2010	36,739,074.10	247,569,627,861.36	176,467,881.73	5,084,034,723.43
2011	33,554,328.70	211,256,880,864.40	138,036,809.70	4,896,398,763.30
2012	36,776,218.70	227,783,180,213.04	146,155,992.09	5,457,096,787.55
2013	33,732,842.70	197,578,220,798.56	124,551,584.52	5,085,642,905.53
2014	31,259,656.20	262,509,692,834.09	160,023,583.69	5,376,247,753.38
2015	29,007,770.80	528,598,397,420.40	250,309,406.00	11,336,079,408.00
TOTAL	768,797,286.43	3,114,065,177,006.17	2,423,889,847.18	104,693,295,717.58

Source: Fisheries Development Division Annual Statistics Unpublished Reports for year 2015

13.2.2 Fish Processing Establishments

The fish processing industry in Tanzania ranges from sophisticated state of the art facilities (commercial) to small artisanal operations producing traditional fish and fishery products for the domestic market. Artisanal processing involves smoking, dry salting and sun drying. A charcoal type kiln is used and a wire mesh is spread on an enclosed rectangular enclosure because of the shortage of wood, which is used as fuel. Alternatively, dry salting was used for similar raw materials (poor quality tilapia and the Nile perch). Dagaa is sun dried on shore sands, on flat rock or hard and dry soils. This process is not always hygienic because the dagaa is not salted before being dried so as to kill microorganisms.

In 1973, an experimental fish processing plant was established at the Nyegezi Freshwater Fisheries Institute for preparing frozen tilapia fillets, which later on was found to be a less profitable operation than was originally thought (Freshwater Fisheries Institute Nyegezi 1973). This was due to the labour-intensive nature of the operation and the low filleting yields. A better way of trading was the selling of fresh fish or even deep frozen whole fish. The deep-frozen tilapia was sent by air to Dar es Salaam (the Kilimanjaro Hotel) and eventually the market was regular when the National Cold Chain Organization (NCCO), which was selling perishable foodstuffs, was established.

Industrial or commercial processing started when the Nile perch was largely taken by processing plants for filleting. The Nile perch is quite suitable for filleting, yielding 40% fillets and 60% offals. According to Gibbon (1997), in 1996, these factories were a mixed bunch, such as a small converted type godown without running water and with just one or two small plate freezers and small flake ice machines. Kenya was the first country to open bigger processing plants by the end of 1980s. The owners of such plants started buying fresh Nile perch from Tanzania through their agents who were provided with motorized collector boats, vans and trucks.

Between 1992 and 1993, Tanzania imposed a ban on the export of whole (and semi-processed) fish to Kenya and that forced processors to establish processing plants in Tanzania. These new market forces have brought about significant positive changes to fish handling and processing techniques. By the year 2012, there were 13 fish processing plants with a total, combined installed capacity of 1040 tonnes/day (see Table 13.2). However, in the year 2015, only 10 fish processing plants were still operational at the average of 40% of their installed capacity. The other three plants had stopped processing fish due to management problems.

The data in Table 13.2 show a list of the fish processing plants, which are operating in the Tanzanian side. This is the result of the expansion of their processing capacity by upgrading the production line in order to cope with the changes in science and technology. As a result, there was motivation for fishers to harvest more to meet the growing demand, which consequently caused pressure on fish stocks and thus, currently, factories operate under the installed capacity due to the scarcity of fish.

13.2.3 Post-harvest Losses and Processing Methods

Post-harvest losses incurred by Tanzania fisheries are estimated at 25–40% of the total production, of which 10–15% is of the Nile perch. These data were gathered during a study carried out by Nanyaro and Makene (1998) in the Mwanza Gulf on the fish losses at fish landing beaches, fish handling in the water, at the markets and during transportation. These data suggest that there is poor fish handling and

Table 13.2 List of fish processing establishments and their capacity (Year 2015)

S/N	Name of factory and location	Location	Year installed	Installed capacity (tons/day)	Production capacity (tons/day)
1	Vicfish Ltd.	Mwanza	1992	140	55
2	Tanperch Ltd.	Mwanza	1992	120	40
3	Mara Fish Packers Ltd.	Musoma	1992	50	25*
4	Tanzania Fish Processors Ltd	Mwanza	1993	120	70
5	Mwanza Fishing Industries Ltd	Mwanza	1994	60	45
6	Omega Fish Ltd	Mwanza	1997	70	15
7	Nile perch Fisheries Ltd.	Mwanza	1997	100	70
8	Chain Food International Ltd	Mwanza	1999	15	10*
9	Prime Catch (Exporters) Ltd.	Musoma	2000	150	40
10	Musoma Fish Processors Ltd.	Musoma	2001	60	35
11	Kagera Fish Company Ltd.	Kagera	2003	25	10*
12	VicFish Ltd. - Bukoba	Kagera	2005	50	35
13	Tanzania Fisheries Development Company Ltd.	Mwanza	2008	80	30
	Total			1040	415 (40%)

Key: * Currently not operational

processing together with poor infrastructure in the fishing industry in terms of fishing boats, landing sites, fish transportation, storage, pre- and post-processing, handling and poor market conditions.

In order to have a clear picture of the losses, there is a programme of collecting data for post-harvest losses from selected Nile perch processing plants. The programme was started in 1999 with the aim of curbing post-harvest losses particularly of the Nile perch in order to maximise benefits for the riparian communities and the nation as a whole. The data were collected twice a week from each of the following selected fish processing plants:

- Kagera Fish Company Ltd. – Kagera region
- Nile Perch Fisheries Ltd. – Mwanza region
- Tanzania Fish Processors Ltd. – Mwanza region
- Victoria Perch Ltd. (Nee Mwanza Fishing Industries Ltd) – Mwanza region
- Prime Catch Ltd. – Mara region

The average post-harvest losses shown by the data collected from selected Nile perch processing plants for the period 1999–2001, 2002–2005, 2009–2012 and 2013–2015 are given in Fig. 13.3. It is evident that between 1999 and 2001, post-harvest losses per year decreased, followed by an abrupt increase during the period 2006–2007 caused by the implementation of the regulation related to slot sizes in the Nile perch processing plants which stipulates that the Nile perch below 50 cm

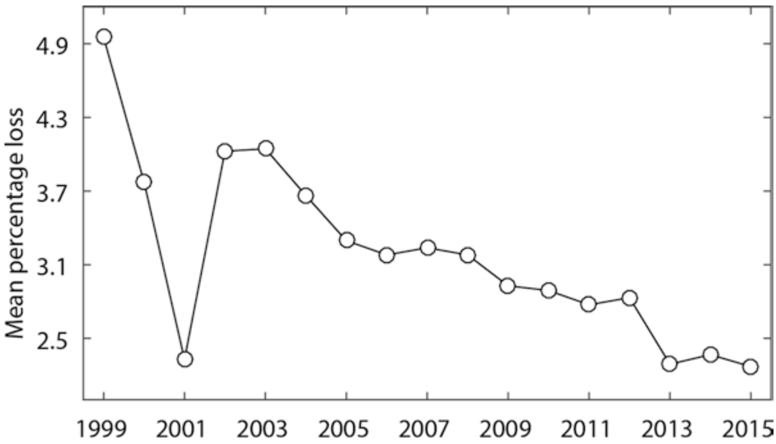

Fig. 13.3 Post-harvest losses for the period 1999–2015

and above 85 cm should not be processed. As a result, the fish used as raw material for producing fillets for export purposes were rejected. Then, from that time, there was a gradual decrease in losses with time, which might have been caused by workers who strictly adhere to their respective Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and Good Laboratory Practices (GLP) as well as the successful adoption of the HACCP plan, in such a way that very minimal alerts related to rejection of fish export consignments have been experienced.

In the case of the Nile tilapia (*Oreochromis niloticus*), which is another important commercial fish species for the domestic market, it is sold in the form of smoked, fresh or frozen fish. Most of these products are of poor quality due to delays in icing, the use of dirty (re-used) ice, long distances from the source to deep freezing points, poor handling practices, unhygienic handling and processing environments, defective cold stores, inefficient deep freezers, poor transportation network and poor packaging, among others. Another important species is dagaa (*R. argentea*). Dagaa are dried by being spread on the ground (sandy beaches) and/or on rocks. In the open drying areas, the end-product is usually full of sand particles and is therefore of low quality in terms of microbial counts, because the drying places are unhygienic, i.e. dirty beach environments with insects like blow-flies that are associated with human and animal activities.

13.2.4 Inspection at Fish Landing Sites

Tanzania has trained fisheries staff (long and short-term training) and members of the Beach Management Units (BMUs) for fish quality assurance purposes. A total of 120 local fish inspectors (district fisheries officers) are available in the Lake Victoria Zone and are trained in the areas of fish handling and processing practices, identification of poisoned fish, the use of all checklists at landing sites and the sampling protocols of fish, water and sediments from the lake. They are responsible for fisheries management, including monitoring, control and the implementation of quality and safety standards.

13.2.5 Gazettement of Fish Landing Beaches

A fish-landing site refers to a specified selected site along the beach where fishers offload their catch for the first time after fishing. The site should be big enough to accommodate many boats, fishers and traders. It should allow future developments such as the building of workshops for traders and processors, ice plants and other necessary facilities like jetty, toilets and the provision of clean running water. The site should be accessible to traders. Sheltered areas like bays with all-weather roads are highly recommended. The selected area should be free of any pollutants and siltation, with deep water to allow boats or fishing vessels of different sizes to anchor.

According to the Frame Surveys of Lake Victoria of 2000, 2002 and 2004, the number of fish landing sites on the Tanzanian side of the lake was 598, 594 and 575, respectively. These sites are spread over 1150 km on the coastline. Out of these, there is a total of 53 identified fish landing sites for gazetting and improvement. The facilities, which should be provided include clean running water, toilets with showers, clean containers for holding ice and offices for the management of sites. In the meantime, 27 out of the 53 fish landing sites have already been improved along the Lake Victoria zone. The improvement of fish landing sites is mainly designed in different levels depending on accessibility and topographic nature. Based on these criteria, the following 10 sites have already been facilitated with floating barges and other sanitary facilities: Kayenze and Mihama (Ilemela District); Namasabo (Ukerewe District); Nkome Mchangani (Geita District); Lukuba Island (Musoma Rural); Nyang'ombe (Rorya District); Kome and Kijiweni (Sengerema District) and Igabilo (Bukoba Rural). The other 11 fish landing sites have received shacks, slabs and toilets for public use. In addition to that, there are six fish landing sites constructed by putting in place shacks, offices, workshop, conference hall, toilet, fence and guard house, these are Kigangama (Magu District); Kahunda (Sengerema District); Kikumbaitare (Chato District); Marehe (Bukoba Rural); Bwai (Musoma Rural) and Sota (Rorya District). The main objective of the intervention is to improve the quality of landed fish and of fish handling, processing and marketing.

13.2.6 Contamination Levels at Landing Sites and Factories

The microbiological pesticides, heavy metals and trace elements in the commercial fish species, water and sediments of Lake Victoria have been monitored for many years. The National Fish Quality Control Laboratory (NFQCL), which is located within Nyegezi in Mwanza, became operational in 1997 and it deals with microbiological and chemical analyses. The laboratory analyses about 2000 samples a year. These include fish, water, sediment, fish and animal feed samples. About 80% of samples are from internal inspectors and 20% from external customers (companies, research). There are microbiological checks of about 1200 samples per year. They also conduct chemical analyses of about 800 samples per year after the beginning of operations.

The area of microbiological checks in fish and fishery products was accredited in 2007 for six parameters, namely Anaerobic Plate Count, Coliform, *Escherichia coli, Enterobacteriaceae, Staphylococcus aureus*, Salmonella, *Vibrio cholerae* and *V. parahaemolyticus*. It is accredited by South African National Accreditation System (SANAS) but from 2013, NFQCL had expanded its scope of accreditation by adding seven more parameters, namely, *V. parahaemoliticus*, *E. coli* for food and total plate count (TPC) (at 22 °C and 37 °C), *E. coli* (at 37 °C and 44 °C) and total coliforms to cater for water samples. However, the Fisheries Development Division has established a chemical laboratory wing by procuring modern equipment namely AAS, GC-2010, GC-MS/MS, LC-MS/MS, F-AAS Varian 280, GF-AAS Varian 280 and CETAC – Mercury Analyzer, Microbeta and Sonicator for biotoxins and it has initiated a process of being accredited, while it is in a stage of establishing a quality management system. Despite these achievements, in the meantime, Tanzania has no accredited laboratory to analyse pesticide samples for samples of fish, water and sediments, thus samples are sent to the South Africa Bureau of Standards (SABS), which is an accredited laboratory for pesticides and heavy metal residues analysis.

Microbial Checks

Microbial checks are carried out in order to verify the quality and safety of fish and fishery products from all Nile perch processing plants. Samples of fish fillets are collected at least twice a week from each factory and analysed for the total plate counts (TPC), total coliforms (TC) and *S. aureus.* In addition, pathogenic bacteria, including *Enterobacteriaceae* spp., *V. cholerae*, *Salmonella* spp. and *Shigella* spp. are also analysed. Likewise, fish processing plants have their own in-house laboratories for the same purpose.

The results of testing the TPC, the TC, *S. aureus, V. cholerae, Enterobacteriaceae* spp. and *Salmonella / Shigella* spp. in the Nile perch fillets collected from fish processing plants are summarised in Table 13.3. The results obtained from a monitoring programme showed that *V. cholerae* and *Salmonella / Shigella* spp. were not detected in any Nile perch fillet samples collected from fish processing plants. This indicates that there is compliance with quality standards. In case of TPC, TC and *S. aureus,* the results obtained showed that the levels of bacterial counts for the samples collected from fish processing plants were within international standards (see Table 13.3).

Table 13.3 List of micro-organisms and recommended limits

	Mean value of counts/year					
Parameter	2011	2012	2013	2014	2015	Standard
Total plate counts/g	2.5 x 10^4	2.8 x 10^4	2.9 x 10^4	3.9 x 10^3	3.0 x 10^3	1 x 10^5
Total coliforms (CF)/g	3.7 x 10^1	4.7 x 10^1	2.7 x 10^1	2.3 x 10^1	1.6 x 10^1	4 x 10^2
Staphylococcus aureus/g	2.0 x 10^1	0.1 x 10^1	2.3 x 10^1	1.0 x 10^1	1.2 x 10^1	1 x 10^3
Enterobacteriaceae CFU/g	8.7 x 10^1	6.5 x 10^1	8.7 x 10^1	2.7 x 10^1	3.8 x 10^1	1 x 10^3
Salmonella and *Shigella* spp. /25 g	ND	ND	ND	ND	ND	NA
Vibrio cholerae/g	ND	ND	ND	ND	ND	NA

Note: ND means Not detected and NA indicates Not available (absent). Data from The National Fish Quality Control Laboratory Nyegezi (2015)

Pesticide Residues

Pesticide levels are monitored because they are used in agricultural activities in the three regions, and due to the allegation made in 1999 by the European Union (EU) that the fish and fishery products from Lake Victoria contain pesticides. Monitoring is done quarterly for the Nile perch fillets from fish processing plants and twice per annum for the lake fish, water and sediments. The collection of fish fillets from fish processing plants and fish, sediments and water from Lake Victoria, started in 1999 and involved 23 sampling stations.

The criteria for the selection of these sampling stations are: (i) the likelihood of risks arising from agricultural and land use practices as well as the wash down from rains, (ii) places (landing beaches/fishing grounds) where there are big volumes of fish and intensive fishing and (iii) areas with the possibility of pollution from industries and mining areas. The common pesticide residues, which are normally assessed in fish fillets samples, whole fish, water and sediments) are given below.

Polychlorinated Biphenyl (PCBs)

- 2,4′-Dichlorobiphenyl (PCB-8), 2,4,4′-Trichlorobiphenyl (PCB 28)
- 2,2′, 4,5,5′-Pentachlorobiphenyl (PCB 101)
- 2,2′, 3,4,4′, 5′-Hexachlorobiphenyl (PCB 138)
- 2,2′, 3,4′, 5,5′-Heptachlorobiphenyl (PCB 180)
- 2,3,3′-Trichlorobiphenyl (PCB 20)
- 2,2′, 5,5′-Tetrachlorobiphenyl (PCB 52)
- 2,3′, 4,4′, 5-Pentachlorobiphenyl (PCB 118)
- 2,2′, 4,4′, 5,5′-Hexachlorobiphenyl (PCB 153)

Organochlorines (OCs)

Alpha-BHC, Lindane, Heptachlor, Aldrin, DDT (sum of op-and pp.-DDT), pp.-DDE and pp.-DDD), Dieldrin, Methoxychlor, Endosulfan *alpha* and *βeta.*

Organophosphates (OPs)

Dichlorvos, Mevinphos, Sulfotep, Diazinon, Parathion-methyl, Chlorpyrifos-methyl, Fenitrothion, Pirimiphos-methyl, Malathion, Parathion, Chlorpyrifos, Chlorfenviphos and Profenophos.

Pyrethroids (PT)

Cyhalothrin, Cyfluthrin, Cypermethrin and Detamethrin.

None of these pesticides, however, were detected (ND) in fish, water and sediments (see Table 13.4) for the period of 2008 up to 2015. According to EU Directives 86/363/EEC for foodstuffs of animal origin as amended by Council Directive 2000/24/EEC for part A of Annex II, the Maximum Residue Allowance Levels (MRLs) for PCBs is 2 mg/kg and for the organochlorides (OCs) and organophosphates (OPs), MRLs is 0.05 mg/kg.

Table 13.4 Results of pesticide residues in fish, water and sediments

Description of pesticide residues		2008	2009	2010	2011	2012	2013	2014	2015
Polychlorinated biphenyls (PCBs)	Fish								
	Water	ND	ND	ND	ND	ND	ND	ND	ND
	Sediments								
Organo chlorines (OCs)	Fish								
	Water	ND	ND	ND	ND	ND	ND	ND	ND
	Sediments								
Organo phosphates (ops)	Fish								
	Water	ND	ND	ND	ND	ND	ND	ND	ND
	Sediments								
Pyrethroids (PT)	Fish								
	Water	ND	ND	ND	ND	ND	ND	ND	ND
	Sediments								

Source: The National Fish Quality Control Laboratory Nyegezi. Key: *ND* Not Detected

Heavy Metals and Trace Elements

Heavy metals and trace elements in fish, water and sediments are normally assessed in order to monitor the possibility of pollution from industries and mining areas. Several studies were conducted between 1996 and 2003 on heavy metal pollution in Lake Victoria (Ikingura and Akagi 1996; Migiro 1997; Kondoro and Mikidadi 1998; DHV Consultants BV 1998; Mohammed 2000; Campbell 2001; Kishe 2001, Kishe and Machiwa 2003; Machiwa et al. 2003). The analysed heavy metals in fish samples were arsenic, copper, zinc, lead, cadmium, chromium, mercury and nickel (see Table 13.5). The Nyegezi laboratory has a monitoring programme in which samples of fish, lake water, and sediments are collected twice per annum.

The results obtained showed that heavy metals and trace elements in whole fish and Nile perch fillets were below the Maximum Allowable Levels (MALs) as developed by the EU and Codex/WHO (Table 13.5).

Currently, samples of fish tissues (muscles), fish liver, gills, gas bladder, and bile juice collected in May 2013 from Nile perch specimens larger than 60 cm TL were analysed at the National Fish Quality Control Laboratory at Nyegezi. There was a particular focus on the contamination from heavy metals like cadmium, zinc, lead and mercury. The results obtained are shown in Table 13.6.

The distribution of heavy metals in Water and Sediment samples analyzed were in the order Pb > Zn > Cd in water, and as Zn > Pb > Cd in sediment. The distribution of heavy metals in selected organs analyzed were in the order Gill > Liver > Muscle. The distribution of heavy metals in all fish organs analyzed was in the order Zn > Pb > Cd.

Table 13.5 Results of assessment of heavy metals in fish flesh (muscle) in mg/kg

Heavy metals and trace elements	Results in μg/kg						Standard (MAL (mg/Kg))	
							EU	CODEX
Arsenic	<1	<1	<1	<1	<1	<1	0.00	0.00
Cadmium	<1	<1	<1	2	<1	<1	0.05	0.00
Copper	330	165	192	232	103	134	0.00	0.00
Chromium	<1	<1	<1	<1	<1	<1	0.00	0.00
Lead	5	11	4.5	11	7	8	0.20	0.00
Mercury	3	143	150	148	49	78	0.50	0.00
Nickel	<1	<1	<1	<1	<1	<1	0.00	0.00
Zinc	8257	9001	8357	12,040	753	3086	0.00	0.00

Source: The National Fish Quality Control Laboratory Nyegezi

Table 13.6 Mean concentrations of heavy metals in water, sediment and selected organs of *Lates niloticus* caught in Lake Victoria from May 2013 – October 2013

Metal	Standard (MAL) WHO/FEPA	Water (mg/l)	Sediment (mg/kg)	Liver (mg/kg)	Gills (mg/kg)	Fish Muscle (mg/kg)
Lead (Pb)	2.0 mg/kg	0.62 ± 0.214	1.45 ± 0.379	1.13 ± 0.114	0.72 ± 0.223	0.33 ± 0.145
Zinc (Zn)	0.20 mg/kg	0.27 ± 0.218	1.92 ± 0.981	1.28 ± 0.393	3.28 ± 0.818	0.75 ± 0.086
Cadmium (Cd)	0.005 ppm	0.003 ± 0.002	0.05 ± 0.011	0.02 ± 0.008	0.02 ± 0.014	0.01 ± 0.003

Source: National Fish Quality Control Laboratory Nyegezi 2013; Key: Values are expressed as mean ± SD of observation

13.2.7 Fish Factories with Hazard Analysis and Critical Control Point (HACCP) Plans

The Hazard Analysis and Critical Control Points (HACCP) is a preventive system of control designed to minimize or eliminate the risk of food safety hazards. The HACCP was developed in 1991 by the EU, through Directive 91/493/EEC and the United States Food and Drug Administration (USFDA, USA) in December 1995 in order to systematically manage all the stages of production with a focus on prevention of any hazards that might arise in physical, biological or chemical form; which might also be caused by the species and its environment or by the processing methods. The system requires fish processing plants to understand the hazards and use hazard prevention methods during processing. In addition, fish factories are required to document the operation of their systems.

In Tanzania, the implementation of the HACCP system throughout the production chain has been adopted since 1997. The traditional one which required the testing of the end-product has been abandoned and replaced with the HACCP system. All the eight operational Nile Perch processing plants have adopted the Hazard Analysis and Critical Control Point programme and the workers adhere to their respective Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and Good Laboratory Practices (GLP). Due to the successful adoption of the HACCP plan, a fish export ban imposed by the EU countries in March 1999 was lifted in October 1999 and the export of the Nile perch resumed in February 2000.

13.2.8 Areas of Harmonisation

Lake Victoria, being a resource that is shared by Kenya, Tanzania and Uganda, requires a collective approach for dealing with its various issues. The riparian states have decided to harmonise their National Fisheries Laws, various management measures and Fish Quality Assurance guidelines for sustainable conservation, management and development of the lake. The major objectives of the Fish Inspection and Quality Assurance (FIQA) harmonization efforts are:

- To ensure that the same standards pertaining to fish quality assurance and safety are commonly applied in the three riparian states;
- To ensure safety and uniformity of the quality of fish and fishery products from the three riparian East African states for both internal and export markets;
- To lay the ground for the establishment of a regional referral laboratory, documentation systems, information dissemination and storage;
- To put in place, the provisions of the East African Community Treaty on the standardization, certification, harmonization, sustainable natural resources management and their rational utilization, among others; and
- To guarantee long-term sustainable economic benefits to the people of East Africa.

A comprehensive Code of Practice with a detailed Inspectors' Guide and Manual of Standard Operating Procedures (MSOP) for aquaculture and fisheries is being developed for use by the partner states.

13.2.9 Legislation on Fish Quality Assurance

The importance of legislation with respect to fish quality and safety assurance was emphasized even in the 1950s when the Fisheries Ordinance was enacted. The ordinance dealt with marketing boards and in 1961 it was found inadequate for independent Tanganyika. As a result, a new Fisheries Act No. 6 of 1970 and Fisheries Regulations were prepared and there was a section in the law that dealt with the improvement of sanitary conditions in the handling and marketing of fish. The Fisheries Act of 1970 was followed by the Food Act No. 10 of 1978 and the Fish Quality Control and Standards Regulations of 2000. The new National Fisheries Policy of 2015 does provide policy direction on matters pertaining to fish quality assurance, whereas the Fisheries Act No. 22 of 2003 and its Regulations of 2009 provide for adequate implementation of the safety and quality of fish and fishery products from the point of capture to the consumer.

13.3 Discussion

Fish quality assurance can be traced from fishing operations where proper handling of fish is advocated to the processing of fish in the factories. During LVEMP I, certain innovations and technologies were undertaken such as improving floating barges and designing and modifying fishing boats, collecting boats and trucks for handling fish and today these initiatives are yielding good results. Efforts are being made to promote powered boats instead of sails and canoes because they are faster and therefore have no adverse effects on quality caused by delays in harvesting time and transportation. In order to monitor the trend of improvement, data for post-harvest losses at selected fish processing plants are collected and analysed.

Investment in a fish business for external markets requires careful consideration of the available fishery resources intended to be processed and then distributed. The export of fish from Lake Victoria started before the 1950s. Most of the fish and fishery products exported then were in the form of fresh, dried, smoked and salted fish. The export business, from the 1950s to the late 1980s was dominated by traders taking the fish and fishery products as far as Burundi, the Democratic Republic of Congo, Rwanda, Malawi, Kenya and Uganda. During this period, there was little information on these activities and there was no proper monitoring of records on the export of fish.

This export market had been in its infancy up until the early 1990s, when the Nile perch industrial processing emerged and dominated the export market. The successful growth in the export of fish and fishery products led to the introduction of a retention scheme in the Fisheries Development Division in 1996 to avail sufficient funds for monitoring, controlling and surveillance in the areas of harvesting, landing, processing and distribution.

The total export of Nile perch products for 14 years (1993–2007) showed a significant increase in weight. This means that our products met customers' requirements at the same time raw materials for processing were available. However, in 1999 there was a remarkable decline in the total export of Nile perch products. In that year, only 25,914.079 metric tonnes valued at US$ 55,321,521.5 (F.O.B. value) were exported. This decline in the export of Nile perch products was caused by the 11-month European Union import ban on Nile perch products from the lake, which began in March 1999 and ended in February 2000.

The same thing happened in 2002 when the slot size of 50–85 cm for Nile perch was implemented in order to curb the processing of immature fish in the riparian states. The total annual export was 29,212.3 tonnes valued at US$ 88.2 million. The Lake Victoria Fisheries Organization (LVFO) Council of Ministers has directed the fisheries departments of the three countries to implement various management measures including the slot size in order to sustain the fishery resources of the lake. As a result, a smaller quantity of raw materials was available for processing due to the fact that most of the fishers were forced to change their fishing nets.

According to FAO (2000), the Nile perch fishery started in the early 1980s and grew to about 43,000 metric tonnes in 1985 and reached a peak in 1990 when 180,000 metric tonnes were recorded before they started falling to about 152,000 metric tonnes in 1996. Mkumbo et al. (2000) estimated that the *L. niloticus* landings increased from 116,462.25 tonnes in 1999 to 138,323.85 tonnes in 2000. Generally, statistics on the export of the Nile perch showed fluctuations with a peak in 2004 when a total of 42,354.5 tonnes, valued at US$ 100,079,167.16 (F.O.B. value) were exported.

Currently, these fish processing plants operate below their capacity due to an inadequate supply of raw materials (the Nile perch). This was caused by the processing plants upgrading their production lines in order to cope with changes in science and technology and to compete effectively. The total combined installed capacity is 1040 tonnes/day while the average processing capacity is only 40%. The data show that there is a need to control the fish processing capacity in the three riparian states in order to avoid the loss of socio-economic benefits.

The post-harvest losses data collected from the selected Nile perch processing plants are used as an indicator of improvement or failure in the handling and preservation of raw materials (the Nile perch) at harvesting, landing beaches, during transportation and processing of the materials in the establishments. Generally, it has been found that there was a gradual decrease in the Nile perch post-harvest losses for 11 years. This decrease was attributed to several factors, including: (i) training of the stakeholders, e.g. fishers, fish collectors, fish processors and other fish handlers in the landing sites in the aspects of fish quality control and safety assurance; proper use of ice; and (ii) good design of the fish handling and transportation facilities such as insulated fish containers and box body transport trucks used in the storage of ice and transportation of raw fish. However, little information is available on the post-harvest losses of the other two commercial fish species, i.e. *O. niloticus* and *R. argentea.*

Although there is a big number of fish landing sites compared to the staff available, all the activities related to fish receiving, weighing, washing, sorting and selling of fish to fish collectors and other traders supplying fish to domestic markets are under control. This is possible because most of the operations and maintenance of these sites are the responsibility of local authorities such as village governments and Beach Management Unit members.

The introduction of floating platforms and racks for fish handling and landing has considerably minimized the contamination of fish by contaminants in terms of chemicals and microbes because before these measures were introduced, fish were landed on polluted water and sand where microbial loads are high. Also, the provision of trays for holding fish and the construction of toilets for public use have improved fish quality and beach hygiene and sanitation.

The determination of the level of contamination at both landing sites and fish processing plants is inevitable because most consumers are assured that the fish and fish products from Lake Victoria meet appropriate standards for safety, quality and integrity. Furthermore, the National Fish Quality Control Laboratory was established for verification of the effectiveness and efficiency of the quality management systems in fish establishments.

Apart from the adoption of HACCP programme in production lines, there are environmental problems related to the fish processing industry. These include poor treatment of wastewater and fish remains, poor sanitation on the beaches due to high population growth and lack of sanitation facilities. All these have negative impacts on the environment such as water and air pollution and the transmission of water borne diseases to the riparian communities. In addition, polluted waters and contaminated beaches affect the quality of fish. Therefore, the HACCP programme should be emphasized at all levels. The deterioration of fish starts soon after the fish have been caught; thus, any temperature abuse may affect its quality, thereby leading to losses.

13.4 Conclusion

Fish quality control and safety assurance has been successful because the Fisheries Development Division is the competent authority in all matters related to fish quality assurance. Microbial checks are now carried out in the accredited National Microbiological Laboratory. Inspectors have acquired skills and knowledge on matters related to fish quality assurance. The government has gazetted the Fisheries Regulations of 2009, which empower fish inspectors to control and monitor fish quality assurance matters effectively.

The export market has forced the Government to take appropriate measures on issues related to fish quality assurance. These measures include the adoption of the

HACCP programme, and the implementation of GMP, GHP and GLP by all Nile perch processing plants. Others include the provision of floating barges to fish landing sites, portable water, fencing, access to roads and sanitary facilities for the enhancement of resource management. As a result, Nile perch post-harvest losses have been reduced significantly. All these measures are aimed at improving the quality of fish so that the local communities and the nation at large may benefit from Lake Victoria fisheries.

13.5 Recommendations

All fish processing plants operate below their maximum installed capacity due to inadequate supply of fish. At the same time, the demand for fish for both domestic and export markets is growing. This is a motivation to fishers to harvest more fish but it is in sharp conflict with the requirement that Lake Victoria fishery resources must be sustained.

- It is recommended that the riparian states take joint steps to control the fishing effort and the processing capacity of the processing plants. They should introduce quotas for all Nile perch processing plants in the riparian states.
- The private sector should be sensitized and encouraged to invest and produce value added products from the Nile perch and other commercial fish species in order to reduce pressure on the fish stocks, maximize profits and increase socio-economic benefits for the people and the nation.
- The fish post-harvest losses for the three important commercial fish species are not well known. Studies should therefore be conducted to determine post-harvest losses for all the three commercial species (*L. niloticus, O. niloticus* and *R. argentea*) at all levels.
- The Government should speed up the accreditation of the Chemical section of National Fish Quality Control Laboratory at Nyegezi to minimize costs of sending samples outside the country.
- The Government should prepare the necessary conditions for the establishment of a Referral Fish Quality Control Laboratory.

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Chapter 14
Overall Conclusions and Recommendations

Yunus D. Mgaya

Abstract The research conducted on Lake Victoria fisheries over the last few years has revealed a dominance of three commercial species, namely, the Nile perch (*Lates niloticus*), the Nile tilapia (*Oreochromis niloticus*) and the silver cyprinid, *Rastrineobola argentea* ("Dagaa"). Human activities in the lake basin have led to eutrophication, which has altered fish habitats and fish food, consequently affecting the diversity of fish resources of Lake Victoria. The challenges facing the management of Lake Victoria fisheries call for more research into the role of the quality of water in the observed lake-wide ecosystem changes. There is need to have a well-resourced lake-wide monitoring system for collecting limnochemical, ecological, biological, catch and effort data in order to have a scientific basis for an evaluation of the effect of management practices on the exploitation of the fisheries resources.

14.1 Introduction

Synthesis of the literature and data collected over the years has revealed a shift in Lake Victoria fisheries from being dominated by multispecies such as haplochromines, *Labeo victorianus, Brycinus* spp., *Barbus* spp., *Mormyrus* spp., *Synodontis* spp., *Oreochromis esculentus*, and *O. variabilis* to commercial fisheries dominated by three species, namely the Nile perch (*L. niloticus*), the Nile tilapia (*O. niloticus*) and the silver cyprinid, *R. argentea* ("dagaa"). The phytoplankton community has also shifted from a diatom-dominated community to one that is dominated by nitrogen-fixing cyanobacteria, with concomitant increase in primary production. On the other hand, the shift in zooplankton community is manifested in the dominance of small-size species (Downing et al. 2014).

The quality of Lake Victoria waters has also changed over the years due to eutrophic conditions exacerbated by elevated nutrient loadings resulting from human population growth around the lake and subsequent changes in land use (Hecky et al.

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2010). Available information shows that eutrophication is one of the driving forces in the alteration of fish habitats and fish food, which, in turn, affects the bountiful fish resources of Lake Victoria (Downing et al. 2014).

Therefore, the challenges associated with the management of Lake Victoria relate to the difficulty of having a clear understanding of the role of the quality of water in the observed lake-wide ecosystem changes. The other challenge is to understand the fisheries in the light of available stocks, temporal and spatial distribution, habits, breeding, feeding and maximum sustainable yields. Both challenges call for rigorous data collection and a lake-wide monitoring system to collect limnochemical, ecological, biological, catch and effort data in order to have a scientific basis for an evaluation of the effect of management practices on the exploitation of the resources. The intervention made by the Lake Victoria Environmental Management Project (LVEMP I) and other projects, notably Lake Victoria Fisheries Research Project (LVFRP II) and the Implementation of Fisheries Management Plan (IFMP), has generated data and information that have led to a greater understanding of the various aspects of the fisheries of Lake Victoria.

In the course of collating data for the present book, some problems were encountered. For example, time series data for all indicators were not available. However, there were catch and effort data collected over a long period of time, although the quality was questionable and data on some biological indicators were highly fragmented. Even where data collected over a long period of time were available, it turned out that the sampled stations were not the same. Despite these shortcomings, it was possible for us to use the available data to show certain clear trends. With the exception of the statistics on the amount and type of the fish caught which had been collected at Lake Victoria (on the Tanzanian side) for the last time in 1997, there is a substantial amount of data on biological indicators relating to the management and conservation of the resources. The synthesis of these data has come up with conclusions and recommendations that could be used to guide the management of the resources.

14.2 Status of Nile Perch

On the basis of the data presented in this book, i.e. data on the decrease in sizes at maturity (Fig. 4.1), the decrease in catches per unit effort (Fig. 12.6), the increase in the amount of immature fish catches (Fig. 6.6), and the decrease in the mesh size of the nets used (Fig. 11.1), it can be concluded that the Nile perch is being overexploited. The data on fishing show the following trends: (i) a considerable increase in the number of fishermen and fishing vessels for the period 1990–2016 from about 29,095 fishermen and 7,797 fishing crafts in 1990 to 109,397 fishermen and 31,773 fishing crafts in 2016; (ii) a tremendous increase in the number of fishing gear operating in Lake Victoria, for example, the number of longline hooks increased from around 369,444 to 8,163,119 between 1990 and 2016 (Fig. 12.1); and (iii) persistent use of gear below the recommended size and the use of banned gear (Table 11.4, Fig. 11.1).

The use of large scale illegal gear (non-selective and environmentally damaging gears), especially beach seines, increased from about 800 in 1998 to 2,000 in 2016 (Table 11.4), with serious implications for the potential of the resources to renew themselves due to the capture of immature and juvenile fish. The size at first maturity for females and males in the Gulf of Mwanza (1988–1989) was at 110 cm and 60 cm TL, respectively. In 2002, the size at maturity decreased to 77 cm for females and 54 cm for males. Catch per unit effort also showed a declining trend between 1994 and 2016 (Fig. 12.6). The two indicators (Lm_{50} and CPUE) show that Nile perch is being overexploited.

Overexploitation of the Nile perch is a result of the high internal and external demand for the fish. The data in Table 13.2 show that all fish processing plants are currently operating below their capacity due to limitations on the supply of fish. Fish export volumes and value are an indicator of the contribution of the sector to foreign exchange earnings, employment, revenue and income for the fishermen.

Overexploitation of the Nile perch has generated a lot of discussion on its status. While some scientists are arguing that the Nile perch is not overexploited and that the fish stock is far from being depleted—hence management should not focus on input and output controls (e.g. Kolding et al. 2008), others are arguing that the resource is being overexploited and thus recommending that the total fishing effort should be controlled. Both sides have realized that eutrophication plays a key role in the observed dynamics of the exploitation of the Nile perch (e.g. Taabu-Munyaho et al. 2013, Downing et al. 2014). This therefore, calls for the integration of environmental and fisheries research and management activities and to the adoption of an ecosystem-based approach to fisheries management.

14.3 Overall Recommendations

The following recommendations are made for fisheries research and fisheries management activities:

14.3.1 Fisheries Research

- Monitoring of the established indicators should be continued and funds should be made available for this purpose. This will facilitate tracking of fluctuations in fish populations vis-à-vis changes in environmental parameters.
- Gaps in the information on fisheries and the environment should be addressed. This will provide empirical evidence that links changes in the environment with fluctuations in fish stocks and biodiversity.

- The role of the lake environment (e.g. eutrophication, toxic blue-green algae, anoxia, etc.) in influencing fisheries productivity should be systematically studied and the results should be applied in the management of fish stocks.
- Biodiversity hotspots and fish breeding habitats, including riparian wetlands, small water bodies and river mouths, should be identified, mapped and protected through the enactment of a law to protect them from haphazard encroachment.
- Persistent occurrence of health problems relating to poor hygiene amongst the fishing communities is attributed to little sensitization and poor formal education. Consequently, there is a need to sensitize communities on hygienic practices and standards so that they may be free from health problems.
- A multi-sectoral and interdisciplinary approach involving all stakeholders in restoring the quality of the waters of Lake Victoria should be developed.
- The decline in fish production levels should be investigated.

14.3.2 Fisheries Management

- There is a need to create alternative income generating activities, which will enable fisherfolk to earn better household incomes and draw their attention away from Lake Victoria. One of the most viable alternative income generating activities for the fisherfolk is aquaculture.
- The Local Governments should take the lead in developing aquaculture as an income generating activity. This should be closely accompanied by the development of hatchery technology to ensure a steady supply of fingerlings.
- In order to ensure rational, optimal and sustainable utilization, and protection of the resources, there is a need to strengthen the co-management programme and improve monitoring, control and surveillance. It is therefore recommended that the Fisheries Development Division sustain its support to activities in the lake zone.
- There is need to establish a database for fisheries that includes types of boats, sizes of boats, the number of fishermen, type of fishermen, types of gear used, etc. and this should be updated frequently. The Fisheries Development Division should set aside some funds for establishing the database.
- The collection of Lake Victoria fisheries statistics should be revamped and strengthened. The Fisheries Development Division needs to collaborate with other stakeholders, including development partners to ensure that fisheries statistics are collected on a regular basis at all levels.
- The complexity of the environment and the activities call for the involvement of all stakeholders in the management of the lake and its fisheries. To this end, science and technology should be used in addressing environmental and management challenges facing Lake Victoria.

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