A Study on Aquatic Biodiversity in the Lake Victoria Basin

EAST AFRICAN COMMUNITY
LAKE VICTORIA BASIN COMMISSION

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ACRONYMS

CBD	Convention on Biological Diversity
COP	Conference of Parties
EAC	East African Community
EAFRO	East African Fisheries Organization
EU	European Union
IFMP	Integrated Fisheries Management Plan
KMFRI	Kenya Marine Fisheries Research Institute
KWS	Kenya Wildlife Service
LVB	Lake Victoria Basin
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Environmental Management Project
NaFIRRI	National Fisheries Resources Research Institute
TAFIRI	Tanzania Fisheries Research Institute
TANFIS	Tanzanian Fisheries Information System
TDA	Trans-boundary Diagnostic Analysis
TORs	Terms of Reference
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
WCMC	World Conservation Monitoring Centre
FAS	Foreign Agricultural Service
PECAD	Production Estimates & Crop Assessment Division
CITES	International Trade in Endangered Species
CBD	Convention on Biological Diversity
BOD	Biological Oxygen Demand
CAS	Catch Assessment Surveys
CITES	Convention on International Trade in Endangered Species
GISP	Global Invasive Species Programme
IMCE	Inter-ministerial Committee for Environment
ILRI	International Livestock Research Institute
IUCEA	Inter-University Council for East Africa
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unregulated and Unreported
KEPHIS	Kenya Plant Health Inspectorate Services
MDGs	Millennium Development Goals
NAWESCO	National Wetland Steering Committee

NEMA	National Environmental Management Authority
NORAD	Norwegian Agency for Development Cooperation
NWP	National Wetlands Programme
NWSC	National Wetlands Standing Committee
RELMA	Regional Land Management Unit
SIDA	Swedish International Development Cooperation Agency
SIMMORS	Sustainable and Integrated Management of the Malagarasi-Muyovozi Ramsar Site
SOPs	Standard Operating Procedures
SWBs	Small Water Bodies
VicRes	Lake Victoria Research Initiative (SIDA)

FOREWORD

The Lake Victoria the second largest lake in the world with an area of 68,800 km2 is well connected to a number of satellite lakes and rivers. The lake had by the turn of 20th century high fish species diversity of over 500 species most of which were endemic to the lake and were of economic and scientific value.

he Lake attracts a lot of interest as demonstrated by the massive amount of research carried out and number of projects implemented. This has generated considerable amount of data and information which is available in different places and forms. Whenever such information is available, its distribution is either highly restricted or accessibility is very limited. There is no complete list and description of the diversity of both flora and fauna in the Basin. Current efforts are uncoordinated as there is no single centralized database on lake's biodiversity to provide information on existing data, ongoing data requisition or even new initiatives.

In view of the above, Lake Victoria Basin Commission with financial support from the Lake Victoria Basin Partnership Fund, commissioned a study on aquatic biodiversity in the Lake Victoria with the objective of providing a centralized access point for information and data for management of aquatic biodiversity in the LVB.

The study involved review aquatic LVB biodiversity information and data, developing formats, collating, transcribing and archiving existing information. The end product was the designing and implementing Bio-diversity Meta-Database which is anchored and accessible for free at the Lake Victoria Basin Commission website (www.lvbcom.org).

The meta-database on aquatic biodiversity of the LVB brings together data and information on aquatic biodiversity which is in the public domain and referenced data which is under the experts and institutions that collect it. The database provides a central location where the aforesaid data and information can be accessed, processed and used by various stakeholders for conservation of biological diversity, sustainable use of its components, and equitable sharing of the benefits from the genetic resources.

This report provides a beginning point for data and information sharing among the stakeholders in the Lake Basin. I urge all players in the LVB to continuously update the database with current data and information.

Dr. Tom. O. Okurut
Executive Secretary
Lake Victoria Basin Commission

EXECUTIVE SUMMARY

Introduction

This is the final report of the study "*Data and Information on the aquatic Biodiversity in the Lake Victoria Basin East Africa*''. This Executive Summary sketches out how the assignment was carried out and the main findings from the study. In chapter 1, the background highlights major geographical features of the Lake Victoria Basin, why aquatic biodiversity is important and the objectives of the study. Methodological aspects of the study are presented in Chapter2. In Chapter 3, a detailed assessment of the components of aquatic biodiversity is given. The components studied are ecosystem (lakes, rivers and wetlands), plants (algae and macrophytes), invertebrates, fish and non-fish vertebrates (amphibians, reptiles, birds and mammals), genetic diversity and the needs of institutions dealing with aquatic biodiversity including policy frameworks. Chapter 4 highlights proposals for tackling biodiversity threats. A prototype meta-database illustrating features from a home page through various screens and populated structure is presented in chapter 5. The report is backed by a Bibliography in Chapter 6, which is also incorporated in the meta-database. Two annexes, one on the consultations made and the other is the Terms of Reference. Therefore, the extended Executive Summary provides outcomes of the assignment from Background through Biodiversity categories to the prototype biodiversity meta-database. This part of the assignment is supplied with the software on CD that was successfully trial-hosted on the web for three weeks and ready for installation.

The Partner States of the East African Community (EAC) designated the Lake Victoria Basin (LVB) as an economic growth zone to be developed jointly by the Partner States. The LVB covers 194,000 km^2, shared amongst Tanzania (44%), Kenya (22%), Uganda (16%), Rwanda (11%) and Burundi (7%). It has about 35 million people with a population density of about 300 persons per km^2 which is higher than national averages for Uganda (235), Burundi (210) and Tanzania (190) but lower than that of Kenya (342) and Rwanda (378). The Lake Victoria Basin Commission (LVBC) is an institution of the East African Community (EAC) responsible for harmonised and coordinated development of the LVB. The vision of the LVBC for the LVB is to have *"A prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits"*.

The LVB has immense natural resources including fisheries, forests, and rangelands which provide livelihood for the communities around the basin. The demands to meet the needs of the rapidly increasing population and domestic animals in form of space, shelter, food, water, health services and the waste disposal, puts very high pressure on the natural resources of the basin. The LVB resources have undergone many negative changes, which threaten the livelihoods of the communities. These changes include a decline in the abundance and diversity of fishes, degradation in water quality and quantity, degradation of the wetlands, rangelands, and the catchment areas.

Aquatic systems comprise one of the most important resources of the LVB covering over 50% of the productive surface areas of the basin. They comprise lakes, rivers, wetlands and the diversity of organisms that inhabit these ecosystems. The ecosystems provide water for domestic, industrial uses and hydro-power generation, while the fishes, other animals and plants provide food, medicine and employment.

Biodiversity is the natural biological capital or wealth of the earth and provides goods and services that support human livelihood. The conservation of biodiversity and its sustainable use offers the means by which humanity can hope to sustain livelihood. Losing genes within species, species within ecosystems and ecosystems within regions reduces the benefits that these systems can supply.In view of the dominant impact of water resources in the LVB on the socio-economic and livelihood of more than 35 million people in the basin, the LVBC considers aquatic biodiversity as a major theme in its mandate.

The LVBC thus commissioned a study on aquatic biodiversity in the basin with the objective of providing a centralized access point for information and data for management of aquatic biodiversity in the LVB. Consequently, the LVBC contracted the National Fisheries Resources Research Institute (NaFIRRI) to review aquatic LVB biodiversity information and data, develop formats, collate, transcribe and archive existing information and design a prototype Meta-Database including procedures for accessing and updating the database. The study was undertaken during October and November 2008.

Approach to the study

This study examined information and data on aquatic biodiversity at ecosystem (lakes, rivers, and wetlands), organism/species (macrophytes, algae, invertebrates, fishes, amphibians, reptiles, birds, and mammals), and genetic levels. This involved, reviewing information, designing data collection formats and collecting information and data on different components of biodiversity, their composition, values, threats, trends, status, legal instruments, institutions and experts, and gaps. The formats developed and the data collected were used to design a prototype Meta database which would be updated from time to time as part of development planning.

Diversity of aquatic ecosystems and taxa

Lake ecosystems of the LVB comprise Lake Victoria and about 50 satellite lakes (15 in Uganda, 13 in the upper River Kagera region of Rwanda and Burundi, 18 in the lower Kagera region of Rwanda and Tanzania, and about 4 in Kenya) and numerous water reservoirs. Lake Victoria is the largest of the LVB lakes occupying 68,800 km^2 (about 35 % of the basin catchment area of 194,000 km^2) and is shared by Kenya (6%), Tanzania (51%) and Uganda (43%). It is part of the Nile basin which is shared by 10 countries of Burundi, Democratic Republic of Congo, Rwanda, Uganda, Tanzania, Kenya, Sudan, Ethiopia, Eritrea and Egypt. It is the second largest freshwater body in the world with a shoreline of 3,440 km, 412 km long and 355 m wide, an average depth of 40 m, maximum depth of 80 m, and a water volume of 2,750 km^3. The lake is estimated to be between 250 – 750 years old and to have earlier dried up twice 200,000 and 12,000 years ago, respectively. It has varied by 2 m in level in the last century due to changes in rainfall, evaporation and outflow. About 82% of the water into the lake comes from direct rainfall and 18% from river inflow. The satellite lakes are shallow, about 4 m deep and connect to the main lake through wetlands and rivers.

There are at least 15 major rivers that flow into Lake Victoria. These are: Sio, Nzoia, Yala, Nyando, Sondu-Miriu, Awach Kendu, and Gucha-Migori in Kenya; Mori, Mara, Ruwoha, Mbalageti, Duma, Magogo, Isanga and Kagera in Tanzania; and Katonga in Uganda. The lake is drained by the White Nile which contributes about 24% of water leaving the lake with the remaining 76% of the water being lost through evaporation. There are also numerous streams connecting to these rivers and lakes.

The LVB wetlands are by far the most extensive in East Africa. There are over 13,000 wetlands varying in size. The major ones include Sango Bay, Nabugabo, Mayanja, Katonga, Sezibwa in Uganda; Nzoia, Yala, Nyando, in Kenya; Mara and the wetlands associated with River Kagera in Tanzania, Rwanda and Burundi. Most of the wetlands are associated with rivers, lake shores and most satellite lakes. There are, however wetlands that are located in closed flood plains with no connection to the lakes or rivers.

The biotic communities associated with lakes, rivers and wetlands include: macrophytes, algae, invertebrates, fishes and non-fish vertebrates (amphibians, reptiles, birds and mammals).

Aquatic macrophytes are the rooted, submerged or floating higher plants associated with aquatic systems. These macrophytes in the LVB are dominated by grasses (Poaceae) and sedges (Cyperaceae) e.g. *Miscanthus violaceus*, *Phragmites mauritianus*, *Cyperus latifolius*, *Typha domingensis* and *Cladium mariscus* sp. *Jamaicense* with papyrus, *Cyperus papyrus* being the most dominant. Emergent macrophytes e.g. reeds and sedges (*Typha, Phragmites, Cyperus papyrus, Vossia*) grow on wet ground or in the shallow littoral zone. Floating-leafed macrophytes such as the water lily (*Nymphaea* sp), pond weed and those that are totally free floating e.g. the duckweed (*Lemna* sp), *Potamogeton*, Nile Cabbage *(Pistia sp)* and water fern (*Azolla)* are also common.

Algae are microscopic photosynthetic organisms ranging from single-celled to complex multicellular to colonial forms that occur in aquatic systems. Some of them are free floating (phytoplankton) while others are either attached (aufuches) or benthic (at the bottom). There are at least 600 species of algae in the aquatic ecosystems of the LVB, comprising diatoms (Bacillariophyceae), blue green algae (Cyanobacteria), green algae (Chlorophyea), brown algae (Chrysophyceae) and dinoflagelletes, (Dinophytes). A comparison of data collected in the 1960s with that collected since the 1990s shows that the diversity of algae in the Lake Victoria has changed from dominance of diatoms to blue green algae. The algal community in the LVB is currently dominated by blue greens, followed by green algae, diatoms, brown algae and dinoflagelletes. The dominance of blue greens is a function of many factors but is greatly influenced by nutrients and light conditions. Low ratios of nitrogen (N) to phosphorus (P) supply favors dominance of blue-green algae, particularly nitrogen-fixing cyanobacteria. Contrary, the concentration of Silicon (Si) has decreased ten times, resulting into changes in the diatom composition from *Aulocoseira* and *Stephanodiscus* in the 1960s to *Nitzchiae* and *Microcystis* presently. Increases in blue-green algal blooms are a threat through oxygen depletion and production of phytotoxin to overall aquatic biodiversity and water environment.

Aquatic invertebrates are organisms that lack a backbone and comprise the small-bodied zooplankton (micro-invertebrates) and the larger macro-invertebrates. Most micro-invertebrates are microscopic and comprise at least 40 species. Cyclopoid copepods are the most abundant and widely distributed micro-invertebrates. The others such as cladocerans and rotifers exhibit variable occurrence and their abundance especially the former is often low. Aquatic macro-invertebrates consist of insect larvae such as *Chaoborus* spp and *Chironomus* spp., insect nymphs, mollusks, crabs (*Potamon emini),* and prawns (*Caridina nilotica)*. Insects are the most dominant of the aquatic macro-invertebrates. Most macro-invertebrates are benthic and live in or near bottom sediments of lakes. Others are partly benthic and pelagic and include the prawn (*Caridina nilotica),* the chaoborid and chironomid larvae, and nymphal stages of various insects. The macro-invertebrate community of Lake Victoria has changed over the last century from a dominance of Chaoborids to that of Chironomids. The zooplankton composition has changed from dominance of the larger calanoid copepods and cladocerans to smaller cyclopoid copepods apparently as a result of size selective predation. The relative proportions of cladocerans and calanoid copepods have decreased, while those of cyclopoids have increased. The shift in algal community from diatoms to cyanobacteria appears to have affected the relative abundance among filter feeding zooplankton. The abundance of prawns which have the capacity to withstand anoxic conditions in Lake Victoria has increased and this contributes to the food of Nile perch.

Fish are aquatic vertebrates that vary greatly in size and are the main aquatic organisms of direct value to man. Current data indicates that there are about 183 fish species belonging to 55 genera, 13 families and seven orders in the basin with 179 fish species in 52 genera and 13 families recorded in 17 lakes; 39 fish species in 24 genera and 14 families recorded in 10 rivers; and 15 fish species belonging to 14 genera and 9 families in the only two wetland ecosystems for which fish data was available. It is considered that prior to fish introductions of Nile perch and the tilapias, there were at least 500 haplochromine cichlid species There have been major changes in fish species composition, abundance and diversity in the LVB. The native tilapiine fishery of Lake Victoria comprising of *Oreochromis esculentus* and *O. variabilis* collapsed due to over-fishing. The riverine fishery comprising of the Ningu (*Labeo victorianus*) collapsed due to fishing at the mouths of rivers at the time fish migrated upstream to breed. The Nile perch *(Lates niloticus)* and four tilapiines (*O. niloticus, Tilapia zillii, T. rendalli* and *O. leucostictus*) were introduced into the lake in the late 1950s and early 1960s to improve fish stocks. The Nile perch depleted endemic fishes especially haplochromines through predation while introduced tilpaiines displaced remnants of endemic tilapiines through inter-specific competition and hybridization. The fishery then shifted to two of the introduced species and only one native species, *Rastrineobola argentea*. Recent data suggests that the fish biomass in Lake Victoria has remained stable around 2 million tonnes between 1999 and 2008 but the contribution of Nile perch to this biomass dropped from 83% to 14.2% whereas that of dagaa increased from 10.5% to 57.3%, respectively and that of haplochromines and other small fishes almost doubled. The fishing pressure on Lake Victoria has increased to the extent that the Nile perch fishery has started to decline. Recent surveys in the main lake and some of the satellite lakes like Nabugabo have indicated signs of re-bouncing of some native fish species. The main resurging fishes represent a few trophic groups and species that occur in large numbers especially zooplanktivores and insectvores.

Amphibians are cold-blooded, smooth-skinned vertebrates e.g. frogs and toads. They live on land but most of them return to the water to breed. The only amphibians recorded in the LVB are frogs and toads. About 31 species were recorded from the LVB in early 2000 and both *Bufo* and *Xenopus* species were common.

Reptiles are air-breathing, cold-blooded vertebrates that have skin covered with scales as opposed to hair or feathers. Reptiles include turtles, lizards, crocodiles and snakes. Most reptiles spend part of their life on land and in water. There is very limited information on the diversity of reptiles in the LVB. About 28 species of reptiles were recorded from the LVB during early 2000.

Birds are warm-blooded, egg-laying, feathered vertebrates with forelimbs modified into wings that enable most of them to fly. Out of 235 freshwater bird species recorded in East Africa, 170 (72%) are associated with the LVB aquatic systems and 88 of these are water birds. The birds use aquatic systems as their habitat and a source of food. Birds are among the top predators in freshwater ecosystems. Birds prefer, muddy, and forested habitats, used mainly for their feeding and refuge. For instance, the kingfisher, the cormorants and pelicans feed on fish. In Uganda, the highest number of birds has been recorded from Lake Wamala followed by Lake Nabugabo. About 105 bird species have been recorded along the shores of the Ugandan part of Lake Victoria while 107 species of birds have been recorded in the wetlands along the Tanzanian shores of Lake Victoria. Some of the birds identified in the LVB wetlands are those that migrate for wintering such as the scolopacidae and stocks. There are a few Important Bird Areas (IBAs) that have been recorded in the Ugandan part of Lake Victoria. These include: The Mburo-Nakivali wetlands, the Sango Bay – Musambwa Islands of Kagera wetlands, the Nabugabo wetlands, the Nabajjuzi wetlands and the Mabamba wetlands.

Mammals are warm-blooded vertebrates characterized by possession of hair on the skin including humans. There is very limited information on aquatic mammals in the LVB. About 44 species of mammals were recorded from the LVB during the first phase of the Lake Victora Environment Management Project (LVEMP1). The mammals which are associated with aquatic systems include Sitatunga, Hippopotamus, and Otters. There are many other mammals which inhabit wetland ecotones out of the need to live in close proximity to water e.g. elephants and buffaloes used to roam the shores of Lake Victoria and its satellite lakes but these are now restricted to national parks due to poaching.

Genetic diversity is the expressions of differences in hereditary makeup of species. Genetically sustainable fisheries should not result in unacceptable loss of genetic diversity and/or unacceptable changes of genetic composition of distinct populations. Loss of populations either through over-exploitation or environmental degradation erodes genetic diversity. Genetic studies in the LVB have focused on commercially important, endangered and introduced fish species. Genetic analysis indicated that individuals of *L. victorianus* were subdivided into genetic groups associated with stream or locality. Initial studies on haplochromine species focuses mainly on species radiation (diversifying lineage), phylogenetics (evolutionary relatedness) and loss of species. The Nile perch that was introduced into Lake Victoria originated from two lakes (Albert and Turkana), containing two *Lates* species. However, it has never been entirely clear which of these became established in Lake Victoria or indeed whether the Lake Victoria population was derived from hybridization between *Lates* species from the two sources. Besides, genetic drift (random changes in relative abundancy of gene variants in a population) caused by the relatively small founder population (approximately 400), the initially slow population increase followed by a period of explosive population growth and selection pressures in the new environment may have resulted in substantial genetic changes. Remnant populations of *O. esculentus* are only found in satellite lakes, while those of *O. variabilis* occur as isolated populations within Upper Victoria Nile, LVB and Kyoga satellite lakes.

Values of aquatic ecosystems and taxa

The major values categories of aquatic biodiversity examined are the direct and indirect use values. Although the direct use values are the ones from which man derives livelihood and assets, indirect use values normally support the direct use values with a change in the indirect use value affecting the direct use value.

The lakes are important sources of water and fish, and they harbor diversity of aquatic organisms. Lake Victoria had very high fish species diversity with more than 500 species, over 90% of them endemic, many of which were decimated by Nile perch predation. The fishery supports the livelihood of about 3 million people and generates fish exports with at least US $ 300 m to the riparian countries. The lake is a reservoir of water for domestic, industrial and agricultural use and generation of hydro-power. The lake assists in modulation of local climate and is responsible for the rainfall upon which agricultural production in the basin depends. The satellite lakes in the LVB have important fisheries and harbor species which have been depleted from the main lake such as *O. esculentus*, and are therefore important in biodiversity conservation.

Rivers and associated streams supply the lakes with water and like lakes provide water for various uses. They have important fisheries such Labeo victorianus, Barbus spp. catfishes and mormyrids which specifically migrate up rivers to breed and return to the lake to feed. Rivers are important in biodiversity conservation because some of the fish species that have been depleted in the main lake still survive in them.

Wetlands have high diversity of plants, animals and soil types. Clay from wetlands is used for bricks and sand for construction. Wetlands have agricultural potential for crops especially rice, aquaculture and they are used for grazing especially during the dry season. Wetlands serve as water reservoirs and assist in maintaining water regimes, climate patterns and conserving soils. Wetlands buffer inputs from the basin into lakes and rivers and serve as sinks stripping, silt, nutrient, pollutants and toxins and are used in sewerage treatment. Wetlands, particularly lakeshore types provide nesting, breeding and nursery habitats for birds, fish and wild animals.

Aquatic macrophytes include species that serve as human food, medicine, fodder for livestock, fuel wood, handcrafts, and breeding and nursery grounds. The aquatic macrophytes used as food include leaves of Amaranthus dubias, Pistia stratiotes, Ipomea aquatica var aquatica, Typha domingensis. Some macrophytes such as Azolla nilotica are used to feed Tilapia in ponds. Others such as Desmodium jamaicance, Ipokea aquatica and Sesbania sesban are important fodder for cattle. Macrophytes like Cyperus cyperus, Phragmites karka and Typha domigensis are used for making crafts while Solanum nigrus has medicinal properties. Aquatic macrophytes serve as primary producers in aquatic food-web. Photosynthesis in the littoral zone results in large input of dissolved and particulate organic matter into aquatic systems. Littoral macrophytes are also useful in stripping pollutants and nutrients from the inflowing water from the catchment areas.

Algae manufacture organic matter through photosynthesis, the basis of primary productivity in the aquatic food chains that culminates in the fish production and release oxygen upon which life in aquatic systems depends.

Invertebrates are a major link between the primary producers (algae and macrophytes) and higher organisms especially fish. Most larval and juvenile fish feed on aquatic invertebrates and some fish species depend on aquatic invertebrates throughout their life. Some invertebrates feed on bottom, decomposing organic matter and assist in removing materials that would degrade the aquatic systems and recycling of nutrients through feeding on sediments. Grazing on algae improves water clarity. The abundance of large-bodied cladocerans and calanoids provides indication of the level of fish predation. Some Chironomidae and Oligochaete species serve as indicators of environmental degradation.

Fish provides animal protein, food, income, employment and foreign exchange earnings. In 2007, Lake Victoria produced about one million tones of fish with a landed value of US $ 340 million and an export value of US$ 308 million.

Knowledge of fish genetic resources help to determine the performance farmed fish and their interactions, including genetic exchange. In capture fisheries, fish genetic resources contribute to the productivity of fished populations and their adaptability to environmental factors such as climate change. Besides determining species characteristics like the degree of inbreeding, genetic information is also useful to natural resource managers in determining the amount of genetic diversity whose loss can be detrimental to populations and affects sustainability. .

Amphibians consume insects; can control pests and some of them like frogs are edible. Tadpoles serve as food of other aquatic predatory organisms including, birds, snakes and fishes. The African frog, *Xenopus* is one of the most widely used laboratory animal. The skins of frogs are sensitive to environmental degradation and their juvenile's can act as indicators of environmental degradation. Frog's skin glands produce a range of substances used in defense against predation and these have been observed to have pharmacological value. Some antibiotics such as those against *Staphylococcus aureus* are based on amphibian excretions.

Reptiles are an important tourist attraction and so, varieties of reptiles are kept in zoos. They serve as biological indicators of the environment. Some feed on rodents which could be destructive to man and his crops and others are edible by man e.g. crocodiles.

Birds are a tourist attraction and bird watching is a major recreational activity in the LVB. The high mobility of birds enables them to move away from unfavorable environments and changes in abundance and distribution can therefore give an indication of environmental health. For instance, the presence and density of Marabou, *Leptoptilos crumeniferus* can give an indication of the poor refuse management of an environment. Some birds like gulls and sterns feed on fish and their concentrations provide fishermen with information of suitable fishing grounds. Birds also return nutrients to lake ecosystems through deposition of the *guano*, nutrient rich droppings.

Water associated mammals like Sitatungas and Hippopotamus are hunted for meat. Sitatunga heads are used as trophies. Other aquatic mammals like Otters are important tourist attractions, pets in zoos and predators of fish in aquatic systems.

Threats and Threatened Ecosystems and Taxa

The threats to lake ecosystems include:

i) declining water levels due to reduced rainfall and increased evaporation
ii) decline in fish species diversity due to over-exploitation of the fish stocks
iii) introduction of exotic fish species especially Nile perch

iv) pollution and eutrophication due nutrients enrichment especially of phosphorus and nitrogen
v) climate change

Lake Victoria has undergone environmental changes over the last century. For instance, the concentration of phosphorus doubled and algal biomass increased 8 to 10 times leading to loss of habitat due to increased anoxia (no oxygen). Lake Victoria is threatened by loss of habitat due to increasing anoxia and predisposed to declining water levels. The diversity of fishes especially haplochromines is threatened by predation by the introduced Nile perch.

Major threats to river ecosystems are:
i) catchment degradation
ii) wastewater discharges
iii) impoundments
iv) over-exploitation of the fishes
v) drought and floods

Degradation of the catchment through deforestation has destabilized water catchments which supply the rivers with water and removal of vegetation along river banks has increased siltation. Extreme climatic events such as floods and droughts have also led to siltation and drying up of the flood plains. Damming of rivers affects migratory species, alters river flow and results in habitat loss while occupancy and agricultural practices on flood plains render them unsuitable as breeding and nursery areas for fish. Fishing at river mouths during periods fish migrate up the rivers to breed has depleted stocks of riverine species. The rivers that flow into Lake Victoria from the Serengeti national park are prone to drought while River Nzoia is threatened by pollution and siltation.

Wetland coverage in the LVB has continued to shrink and their uses and services have deteriorated, mainly through conversion into human settlements, drained for agriculture especially of rice, sugarcane and grazing. LVB wetlands have been polluted by industrial waste and wetland resources especially papyrus, clay and sand are being over-harvested. Some wetlands have been lost due to drought. The Nakivubo wetland in Kampala is threatened by excessive input of municipal waste while the Yala and the lower Nzoia floodplain wetlands are threatened by drainage into farmland.

The diversity of aquatic macrophytes has been affected by over-exploitation, habitat degradation and development along shores of water bodies, reducing the diversity, abundance and distribution of macrophyte cover. Invasive species such as water hyacinth (*Eichhornia crassipes*) have become a menace while papyrus and reeds are the mainly threatened by excessive harvesting.

The main threat to algal species diversity in LVB is the increase of phosphorus and nitrogen concentrations, which have triggered the doubling of phytoplankton production, resulting into a four fold algal biomass increase and ultimately a four fold decrease in water transparency. The increased algal growth coupled with changes in stratification and mixing regimes have led to reduced oxygen concentrations to the extent that up to 50% of the volume of the lake is not habitable by fish for most of the year. Diatoms especially *Aulocoseira spp* are threatened by excessive P input and Si deficiency. Green algae e.g. *Ankistrodemus spp., Pediastrum spp* and *Cosmarium spp.* are threatened by excess P and N deficiency and overgrazing by invertebrates and fish as they are the most preferred taxa due to their high nutritional value. The growth of *Anabeana* spp in Lake Victoria has been reduced by the reduced light intensity.

The main threat of aquatic invertebrates' diversity is environmental degradation leading to loss of habitable space due to increased anoxia and the changing trophic status of the lake. The change in composition of the algal community has had effects on the quality and quantity of algae that the invertebrates could feed on. The changes in fish communities also affected the grazing pressure on certain types of zooplankton because most invertebrates especially copepods have been displaced from deep to intermediate and surface waters due to the spread of anoxia that has made them more vulnerable to selective fish predation. Crustacean zooplanktons are threatened by eutrophication, pollution, anoxia and the changing phytoplankton composition while filter feeding zooplankton such as cladocerans are threatened by the reduction in diatoms and increase in blue greens.

Over-exploitation and introduction of exotic fish species especially Nile perch is the main threat to fish species diversity but water pollution, flow modification, destruction and modification of the habitat and climate change have also had some impacts. Commercially important fish species have been threatened by over-exploitation. Migratory riverine species such as the Ningu are threatened by over-fishing at mouths of rivers as they migrate to breed. Other fish species especially haplochromines are threatened due to predation by the introduced Nile perch. The native tilapiine species are threatened by over-exploitation, competition and hybridization with introduced tilpaiines.

The main threats to amphibians is environmental degradation especially deterioration in water quality and wetland drainage in the LVB. *Xenopus* species are threatened by degradation in the lake environment.

Killing by man due to the venomous nature is one of the threats to reptile. Some reptiles like crocodiles were also earlier hunted to virtual extinction for their skins, even currently; crocodiles are threatened by the hunting.

Threats to aquatic birds include: drowning and getting entangled in nets; loss of feeding, roosting/nesting and breeding grounds, poaching and over-exploitation through trapping of some species. Many water birds use vegetation as refugia/shelter for feeding and breeding, therefore degradation of these habitats through clearing of vegetation affects these organisms. Some of the threatened birds include the Papyrus Gonolek (*Laniarius mufumbiri*) and the Papyrus Canary (*Serinus koliensis*), Carruthers's Cisticola (*Cisticola carruthersi*) and the white winged warbler (*Bradyoterus carpalis*) which have been identified in the wetlands of the Kenyan part of the LVB and are now listed in the East African Red List Data

The major threat to mammals is pouching for meat and habitat loss. Hippopotamus and Sitatungas have been pouched for meat to the extent that Hippopotamus have been hunted to virtual extinction in some parts of the LVBC and are therefore threatened by hunting. Man has also taken over and occupies habitats that used to be occupied by wildlife in proximity of aquatic habitats.

Loss of genetic diversity is detrimental to populations and affects their future sustainability. Reduced genetic diversity can contribute to inbreeding, depression, lower population fitness and reduces the populations' resilience because the population's genetic pool of potential responses to stress is restricted. Genetic diversity indicators have the potential to provide meaningful information about the condition and long-term vitality of aquatic populations. Fishing and aquaculture pose potential threats to genetic diversity of wild fish stocks by reducing population sizes to levels that favour inbreeding and loss of genetic diversity through genetic drift. Fishing certain sizes or age classes may alter the genetic composition of fish population through selection. Fishing also affects natural levels of genetic exchange or gene flow between local populations and eventually genetic population structure such as the initial reduction of native tilapiines (*Oreochromis esculentus* and *O. variabilis*) in Lake Victoria. The displacement in populations of native tilapiines in Lake Victoria has been attributed to hybridization of introduced species with the native species. The native tilapiines species in the Lake Victoria basin are endangered through hybridization and genetic swamping with introduced *O. niloticus*.

Networking of Institutions and Experts

One of the challenges facing management of aquatic biodiversity is the limited sharing and application of data by the institutions and experts who collect and hold the data. These institutions include: Research and management institutions in fisheries, water, wetlands, wildlife and academic institutions (mainly universities); Regional and international institutions; Parastatals and NGOs. The data in these institutions is held either by the institutions themselves or by the experts in different formats including grey literature, field notebooks, excel spreadsheets and limited databases. The infrastructure and human resources capacity for management of data are limited; moreover, there is no clear policy on ownership and sharing of data between institutions and scientists. There is therefore need to improve the capacity of institutions to manage databases and to have clear policies on data ownership and sharing. Institutions could be networked initially at national levels to create national biodiversity databanks and later be linked to create regional databases. The scientists collecting data on specific areas of biodiversity could also be organised into specialist working groups.

Policy and Legal Frameworks

Management of aquatic biodiversity requires that information and data is transformed into guidelines for enabling policies, laws and regulations to control key threats to biodiversity such as loss of habitats, species and genes, pollution, eutrophication and climate change for sustainable development. There are many international policies and legal instruments that address the threats to biodiversity such as the Declaration of the United Nations Conference on Human Environment, Rio Declaration on Environment and Development, the Johannesburg Declaration on Sustainable Development and the Millennium Declaration. Sustainable and equitable use, and conservation of biodiversity are covered by a number of international conventions and protocols such as the Convention for Biological Diversity, The Ramsar Convention, CITES, the Convention on Conservation of Migratory Species of Wild Animals, the Framework Convention on Climate Change, The World Heritage Convention, and the Code of Conduct for Responsible Fisheries. The EAC Partner States have regional policies which cover conservation of biodiversity in the EAC Treaty, the LVFO Convention, the Protocol for Sustainable Development of the LVB, and the Protocol on Environment and Natural Resources Management. The LVFO Council of Ministers has made a number of commitments towards sustainable management of fisheries such as the LVFO Regional Plan of Action to prevent, deter and eliminate Illegal, Unreported and Unregulated (IUU) fishing and the Regional Plan of Action for Management of Fishing Capacity. Individual Partner States have policies, legal instruments and institutions that operationalize the international and regional legal instruments. These are covered in The National constitutions, the National Environment Management Acts, the Water Acts, the Fisheries Acts and the Wildlife Conservation Acts. There are also international, regional and national institutions for managing most aspects of aquatic biodiversity. Application of the different international, regional and national legal instruments has, however generally been weak resulting in continued deterioration of ecosystems, species and genetic resources. There is therefore need to strengthen enforcement of legal instruments including involving of user communities.

Gaps in information and data

The main socio-economic gap identified is the general lack of statistics relating to quantification of both direct and indirect use values of aquatic biodiversity and how they relate to each other.

There is inadequate information and data on satellite lakes and the impact of climate on aquatic ecosystems in the LVB. Rivers and their biotic communities have been less studied than lake ecosystems and yet they are a major link between the catchment and the lakes. Data on characteristics of most river systems is lacking.

There is no clear inventory and demarcation of wetlands of the LVB, and wetland capacities to perform the various functions has not been determined. For instance, the capacity of wetlands to handle large volumes of sewerage is not well known. The financial contribution of wetlands to national economies due to provision of bricks and sand used in construction is worth billions of shillings but has never been quantified.

There is limited information on the inventory of aquatic macrophytes and their role in aquatic ecosystems and there are no specific policies to protect aquatic macrophytes.

Most of the available data on algal species diversity is from Lake Victoria but that from satellite lakes and rivers is scanty or does not exisit at all. Information on the changes in the food-web structure of the micro and macro organisms that feed on algae, status and trends in water quality of most lakes and rivers, nutrient status and pollutant sources into lakes that affect algal biodiversity is also limited

There have been no systematic studies of the invertebrate communities of the LVB especially the satellite lakes and rivers and the value of invertebrates in sustaining fish production and environmental health needs emphasis.

The fishing capacity which the different lakes can support is not known and this has often led of over-fishing due to unguided management efforts. This is because most data on fisheries is on the main Lake Victoria and limited on satellite lakes and rivers. .

Information and data on amphibians, reptiles, birds and mammals in the LVB are limited. This calls for a more detailed inventory study of these animals and a need to study the impacts of the changes in the environment on them.

The focus of genetic studies in the LVB has been mainly on ecologically and economically important fish species. Genetic diversity data on majority of aquatic biota in the LVB is lacking.

Apart from the mandate of handling environmental and biodiversity issues overlapping between sectoral, national and regional institutions; coordination and enforcement of legal instruments in the national and regional institutions are weak. The national policies are not adequately harmonised especially in respect to biodiversity conservation and enforcement.

Recommendations to reduce the threats and fill the gaps

The biggest threat to aquatic biodiversity is the increasing human population and demands it puts on the resources. Since the human population will inevitably continue to increase, what is required is to manage the resources to meet the demands of the increasing population.

There should be quantification and appreciation of the values of different components of aquatic biodiversity either direct or indirect and their implications on livelihoods. Data should be collected on the values of different components of biodiversity and communities should be sensitized especially on the benefits of sustainable use of the resources.

In order to maintain water quantity and quality, water release policy to regulate release of water from Lake Victoria should be developed. Human activities which increase P concentration in the lake e.g. bush burning need to be managed. The impact of climate change on the lake ecosystem is not yet understood. Therefore, in-depth investigations on impact of climate change in relation to the social-politcal situation are required. There is need to protect habitats that conserve of fish species diversity such as marine parks, control degradation of water quality, protect the wetlands around the satellite lakes to facilitate water retention, collect data from satellite lakes to guide their management and identify, map and protect biodiversity hotspots for different ecosystems and taxa.

Catchment activities that degrade riverine habitats must be identified and managed and over-exploitation of riverine fishes during breeding season at the mouths of rivers must be controlled. Data collection on riverine habitats especially on their characteristics, physical environment and biotic communities should be improved and catchments which stabilize ground water supply such as forests must be protected.

All wetlands in the basin need to be inventoried, demarcated and biomass of major wetland commodities determined. In addition, the value of wetlands in performing the various functions such as buffering capacities needs to be quantified in order to, develop wetland management plans and methods for sustainable wetland resource use, protection of wetlands important for biodiversity and strategies to rehabilitate degraded wetlands developed. Inventory of aquatic macrophytes as well as their values must be evaluated so as to develop sustainable use practices.

Since, most of the work on algal studies has been done on Lake Victoria, there is need to carry out similar surveys on other aquatic systems in the LVB to establish status and trends. The composition and distribution of algae that produce toxins must be determined so as to devise mechanisms of reducing their impact on water users.

Aquatic food webs and how the different organisms relate to each other and to overall production of lakes is still not yet clear, thus data on food web components e.g. invertebrate communities especially in the less studies systems, the satellite lakes and rivers has to be to be collected o to improve our understanding.

Endangered fish species in lakes and habitats (refugia) where they are still located need to be identified and protected. Such areas could be designated as marine packs in the LVB. Fishing pressure on the main lake should be controlled and collection of fisheries data on the satellite lakes should be improved. The predatory Nile perch should not be allowed to spread to the satellite lakes where it is absent.

Data and information on higher taxa other than fish e.g. amphibians, reptiles, mammals and birds are limited in the entire basin. There is need therefore for comprehensive surveys to collect data on them and appreciate their role and values to the ecosystem and man. There is need to identify IBAs, sanctuaries and eco-tourism centers within the LVB for protection from human encroachment.

There is need to identify those organisms for which genetic diversity information is required and to collect information on those them. Genetically similar species should not be mixed to avoid hybridization and genetic swamping.

Enforcement of existing legal instruments including involving of user communities should be strengthened and appropriate new ones developed.

Infrastructure and human resources capacity of institutions to manage databases and policies on data ownership and sharing need to be improved. There is need to network institutions at national levels to create national biodiversity databanks and to link them to create regional databases. The scientists collecting data on specific areas of biodiversity could also be grouped into specialist working groups.

Finally, gathering data is not an end to itself but an incremental process that evolves through organizing of existing data and acquisition of more data.   The assignment is therefore to be regarded as part of a continuous process.

1. BACKGROUND

1.1. The Lake Victoria Basin and Its Aquatic Resources

The Lake Victoria Basin (LVB) is located in the central region of East Africa and covers an area of 194,000 km^2 of which 7% is in Burundi, 22% in Kenya, 11% in Rwanda, 44% in Tanzania and 16% in Uganda. Lake Victoria, the second largest lake in the world with an area of 68,800 km^2 is associated with many satellite lakes and rivers. The main lake and satellite lakes are fringed by extensive wetlands. About 35 million people (about 30% of the entire population of East Africa) live and derive their livelihood directly or indirectly from the basin.

Lake Victoria supports one of the largest freshwater fisheries in the world which in 2007 was produced about one million tons of fish valued at US $ 300-400 million The lake had high fish species diversity of over 500 species most of which were endemic and were of economic, ecological and scientific value. Lakes and rivers provide water for irrigation, hydropower generation, industrial and domestic use and are used for waste disposal and modulation local climate. Satellite lakes in the LVB serve as refugia of some of the fish species that have been depleted from the main lake.

The LVB has extensive wetlands, which filter pollutants and other wastes entering the lakes and rivers, hold and regulate the flow of water, provide raw materials for construction and provide suitable habitats for a variety of wildlife including plants, birds and fish, some of which have immense economic, medicinal and food values. However, the aquatic resources of the Lake Victoria basin are under increasing pressure from human induced changes. This is manifested in a decline in the diversity of flora and fauna, and habitat degradation due to increased input of pollutants, industrial and municipal waste, infestation by aquatic weeds especially water hyacinth, de-oxygenation and a reduction in the quantity and quality of water. About 200 out of over 500 species of fish in the main Lake Victoria are estimated to have been depleted following introduction of a large Nile perch (*Lates niloticus*) predator and three tilapiine species in the early 1950s. The wetlands around some of these lakes are being converted to other uses thus reducing the ecosystem functions and the goods and services which they provide.

1.2. The Lake Victoria Basin Commission

The Partner States of the EAC designated the LVB as an economic growth zone to be developed jointly due to its high economic value and the trans-boundary nature of its resources. In 2003, the Lake Victoria Basin Commission (LVBC) was created to spearhead this vision. The LVBC coordinates regional efforts towards sustainable development of the LVB and include conservation and sustainable utilization of key natural resources such as water, fisheries, wetlands, forestry and wildlife. In an effort to implement its mandate, the LVBC developed a Vision of having *“A prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits”*, undertook a Trans-boundary Diagnostic Analysis (TDA) to identify key problems that needed to be addressed and then prepared a Strategic Action Program (SAP) for implementation of the vision. The identified problems included: i) land, wetland and forest degradation

ii) declining fish stocks and fish species diversity
iii) increasing pollution and eutrophication

iv) unsustainable water resources management
v) climate change and declining water levels
vi) weak governance, policy, legal and institutional frameworks.

1.3. Justification for the Study

Despite, immense information being available on the aquatic resources of the LVB, the resources have continued to deteriorate which threatens the livelihood of people who depend on it. The deterioration of the resources has been attributed to intensive non-selective fisheries, activities associated with industrialization, agriculture, dam construction, introduction and invasion of exotic species, and rapid increases in human and livestock population. These have been accompanied by changes in productivity, in physical and chemical conditions in the lake resulting in deterioration and loss of habitat. Some of the key changes include: increase in nutrient loading especially of phosphorus that lead to eutrophication, increase in phytoplankton productivity, enhancement of algal blooms, changes in the composition of the algal community, increased development of anoxic waters in the hypolimnion and a decrease in fish species diversity. The lake's ecosystem has been affected by the introduction of non-native species especially the Nile perch, *Lates niloticus* and several tilapiine species during 1950s and invasion by the water hyacinth, *Eichhornia crassipes* in 1990s. The consequence of these introductions have been a decline in the lake's biodiversity, especially of fish leading to a shift in the fishery from a multi-species fishery to that based two introduced species, Nile perch, and Nile tilapia (*Oreochromis niloticus)* and one native species, *Rastrineobola argentea*. Similarly, there has been a shift in the composition and abundance of the invertebrate and algal communities upon which fish depend for food. Comparable changes have been recorded in some satellite lakes and wetland systems in the basin.

This study arose out of the concern over unprecedented loss of aquatic biodiversity in Lake Victoria and its basin at ecosystem, species, and genetic levels and associated socio-economic losses. Some of the factors contributing to the loss of biodiversity in Lake Victoria and associated aquatic ecosystems in the basin are:
i) interference with inflowing rivers and water extraction,
ii) excessive fishing pressure,
iii) water level changes,
iv) pollution,
v) invasive and introduced species,
vi) climate change,
vii) the open access policy to harvesting most of the natural resources, and
viii) inadequate policies, regulation and weak corrupt enforcement systems.

The high rate of species loss and environmental degradation in LVB suggests that biodiversity is susceptible to threats from pollution, eutrophication, over fishing, invasion of exotic species, and other human activities.

The decline in fish species diversity and environmental degradation are probably the most visible manifestation of the sorry state of biodiversity loss in this fragile ecosystem. The threats to some of the economically and ecologically important fish species (including Haplochromines) heighten concern over general loss of biodiversity. The flagship species such as the haplochromines, *Labeo victorianus* and the native tilapiines (*Oreochromis esculentus* and *O. variabilis*) are now threatened and some are virtually extinct from the main lake. Even the fishery of the Nile perch which flourished since the 1970s has started to signs of being overfished.

More than 35 million people who depend on the lake are feeling the consequences of the changes in the fauna and flora of the LVB. In Lake Victoria, as elsewhere, human welfare is intimately linked to concerns for species conservation and ecosystem integrity. At the moment, much of the fauna and flora of Lake Victoria are being intensively exploited to meet needs of the ever increasing human population but their ecological and conservation status is not clearly known.

Despite considerable amount of research efforts carried out in the region, it is still difficult to obtain information and data for management of aquatic biodiversity in the LVB. However, the uncoordinated nature of the management and storage of data and associated research materials has made their access and usage cumbersome, leading in many instances to apparent duplication of effort. Many species have not been identified and described, which makes the description of both flora and fauna incomplete. This is so especially among the haplochromines. Consequently, several species await discovery and description to the rest of the world. A complete list and description of the diversity of both flora and fauna of Lake Victoria, its associated satellite lakes and wetlands is not in place. Due to the uncoordinated current efforts in biodiversity data collection, there is no single centralized database on LVB biodiversity consolidated to provide information on existing data, ongoing data acquisition or even new initiatives.

1.4. Previous efforts to develop Database on Lake Victoria

The first lake wide survey of Lake Victoria was undertaken by Graham in 1928. This was followed by creation of a regional institution, the East African Fisheries Research Organization (EAFRO) to collect information for management of the fisheries resources and other biological, physical and chemical factors that drive fish production. EAFRO undertook major lake-wide stock assessment surveys between 1969 and 1974 with support of UNDP. Subsequent lake wide surveys were undertaken between 1996 and 2002 by the Lake Victoria Fisheries Research Project Phase II which was funded by the EU and from 1997 to 2005 by the Lake Victoria Environmental Management Project (LVEMP 1) that was funded by GEF/World Bank and from 2003 to 2008 by the Integrated Fisheries Management Plan (IFMP) project funded by the EU. Other institutions especially universities have also generated information and data on Lake Victoria. As a result of these efforts, large amounts of information and data have accumulated on the lake but there is no one stop centre where a significant amount of this information and data is assembled and can be accessed. Although, LVEMPI in 1999 attempted to develop the first regional fisheries database, the efforts did not bear a functional accessible database. Subsequently, the EU funded Lake Victoria Fisheries Research Project LVFRPII attempted to develop a SAMAKI fisheries database and these efforts continued during IFMP into a database called EAFISH. National efforts to create some fisheries databases on Lake Victoria have been limited. For instance, in 1990s the Fisheries Division in Tanzania attempted to create a fisheries database TANFIS while Uganda attempted to create one called UGASTAT but these efforts were mainly limited to commercially important species and appear not to have been sustained.

Research targeting aquatic biodiversity has been limited, save for LVEMPI that did some work in the biodiversity studies. The LVEMP 1 studies mainly provided lists of species with

limited information on the values, threats and trends on which guidance on development of plans for conservation and sustainable use of aquatic biodiversity could be based. Most research in the basin has focused on population dynamics of commercially important organisms especially fish and the factors both human and environmental that affect the stocks.
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1.5. Global perspective of biodiversity

Biodiversity is the variety of life on earth including its interactions with the physical and chemical environment. The goods, services and functions provided by biodiversity include:

i) goods such as food (fuels, genetic resources, bio-chemicals and freshwater);
ii) regulatory services (water purification, erosion regulation, natural hazard protection, disease regulation, pest regulation, climate regulation, regulation of floods, seed dispersal, pollination, herbivory, invasion resistance);
iii) cultural services (recreation and aesthetic values, and supporting services, education and inspiration, knowledge system, spiritual and religious values); and
iv) supporting values (primary production, provision of habitat, water cycling, nutrient cycling, soil formation and retention, and production of oxygen and carbon dioxide).

Globally, biodiversity has continued to reduce, which threatens the goods and services that it provides. Concern over this loss motivated the nations of the world to enter into the Convention on Biological Diversity (CBD) in 1992 with the objective of: Conserving biodiversity, sustainably using its components and equitably sharing of benefits arising out of the genetic resources.

In 2002, the international community adopted a Strategic Plan with goals, targets and indicators to:

i) reduce the rate of loss of biodiversity at ecosystems, species and genetic levels;
ii) promote sustainable use of biodiversity;
iii) reduce threats to biodiversity including invasive alien species, climate change, pollution, and habitat change;
iv) maintain ecosystem integrity;
v) provide goods and services from ecosystems; and
vi) protect traditional knowledge and ensure fair and equitable sharing of benefits arising out of genetic resources.

This requires information and data on the status and trends in distribution and condition of ecosystems, species and genes; distribution and abundance of threatened species; the factors affecting biodiversity and response measures for policy guidance and interventions.

Additionally, guidelines for assessment of biodiversity were provided by the international community. These guidelines involve:

i) identification of the components of biodiversity that is important for conservation;
ii) sustainable use and equitable sharing of benefits;
iii) collection and evaluation of data needed for effective monitoring of the components of biodiversity;
iv) identification of the processes and activities that threaten biodiversity;
v) determination of economic values of biodiversity;
vi) evaluation of economic benefits of conservation and sustainable use of biological resources; and
vii) suggestion of priority actions for conservation and sustainable use of biodiversity.

This requires stock taking through collection of information and data, preparing action plans and evaluating effectiveness of the actions.

Other constraints to conservation and sustainable use of biodiversity that need to be tackled include:

i) inadequate data or limited accessibility to data for biodiversity management;
ii) inadequate policy and legal framework at different levels of governance;
iii) inadequate well defined, effective, efficient and coordinated institutions for providing information and data and for management of biodiversity;
iv) conflicting interests among institutions responsible for biodiversity management;
v) lack of community participation in biodiversity management;
vi) limited public awareness and appreciation of the values and benefits of biodiversity; and
vii) inadequate funding for biodiversity management.

1.6. The Purpose, Objectives and Expected Outputs of the study

The main purpose of this study was to initiate a process of bringing together information and data on aquatic biodiversity of the LVB to a centralized access point to facilitate processing and update of existing and new biodiversity information into a format readily available to the users. The overall objective of the study was to collect, archive and transcribe existing and new aquatic biodiversity datasets for LVB and to develop a system for further development of the database.

2. METHODOLOGY FOR ASSESSMENT OF BIODIVERSITY

2.1. Introduction

This assignment was aimed at taking stock of information and data available on aquatic biodiversity of the LVB, preparing fact sheets, identifying gaps, designing a database and proposing a system for further development of the database. This involved:

i) reviewing existing biodiversity information and data and identifying gaps;
ii) designing data collection formats;
iii) collating data and designing a prototype meta database;
iv) identifying and proposing a system of networking institutions and experts to update the data;
v) identifying gaps in additional data that needs to be collected;
vi) synthesising, and providing a summary of the information gathered in form of fact sheets, and providing recommendations towards biodiversity management and further development and management of the database.

The assignment focused on aquatic ecosystems (lakes, rivers and wetlands), the organism/species in these systems and to a limited extent on genetic diversity of some of the organisms e.g. fishes.

The database was developed on the basis of the guidelines, criteria and targets provided by UNEP, the CBD, and IUCN as in Tables 2.1 and 2.2.

Table 2.1. Criteria for selecting priorities for monitoring biodiversity provided by UNEP the in the CBD

CRITERIA
Data that provide baseline information for monitoring conservation
Data that are important in policy on conservation and sustainable use of biodiversity
Data of actual or potential economic values of biodiversity
Data on ecosystems containing high diversity and large numbers of endemic and threatened species
Data on ecosystems and habitats required by migratory species such as fishes and birds
Data on ecosystems, species and genomes of social, economic, cultural or scientific value
Data on ecosystems and habitats which are associated with key evolutionary and biological processes
Data on species and communities which are of medicinal, agricultural/aquaculture value
Data on plant and animal genetic resources, including medicinal plants, and domesticated breeds
Data on genomes and genes of scientific value and socio-economic importance
Data on species which are wild relatives of domesticated species
Data on indicator species of importance to scientific research into biodiversity
Data on species that serve as indicators of ecosystem health or disturbance
Data on 'keystone' and 'flagship' species and habitats
Data on alien or exotic species which pose threat to biodiversity
Data on the status and distribution of protected areas
Data on biodiversity within conservation/protected areas
Data on species and sites of special significance for conservation of biodiversity outside protected areas
Data on species and communities which are threatened
Data on threats to biodiversity
Data on rates of ecosystem habitat and biodiversity loss
Data on habitat and species distribution
Data on biodiversity and ecosystems functions
Data on socio-economic values of protected areas
Data on policy, legal, institutional and governance issues on biodiversity conservation and sustainable use

Table 2.2. The 2010 biodiversity targets set the international community

	CRITERIA AND INDICATORS UNDER DIFFERENT TARGETS
1	Reducing the rate of loss of components of biodiversity, including habitats, ecosystems, species, populations, and genes
	Trends in extent of selected ecosystems and habitats
	Trends in abundance and distribution of selected high value species
	Change in status of threatened species
	Changes in genetic diversity of species of major socio-economic importance
	Number and coverage of protected areas
2	Promoting sustainable use of biodiversity
	Area of ecosystem under sustainable management
	Number of species under sustainable management
3	Addressing major threats to biodiversity including invasive alien species, climate change, eutrophication, pollution, and habitat change
	Trends in invasive species
	Trends in deposition of pollutants such as phosphorus and nitrogen

	CRITERIA AND INDICATORS UNDER DIFFERENT TARGETS
4	Maintaining ecosystem integrity, and provision of goods and services provided by ecosystems in support of human well-being
	The level of connectivity/fragmentation of ecosystems
	Trend in the quality and quantity of water in aquatic ecosystems
5	Protecting traditional knowledge, innovations and practices
	Status and trends in linguistic diversity and number of speakers of indigenous languages
6	Ensuring the fair and equitable sharing of the benefits arising out of genetic resources
	Trends in sharing of key genetic resources
	Number of policies of equitable sharing of resources
7	Mobilizing financial and technical resources, especially for developing countries for implementing the CBD
	Level of development assistance provided in support of the CBD

2.2. Data collection formats

2.2.1. Formats for ecosystem, organism/species and genetic diversity data

The data on ecosystem, species and genetic diversity and on classification of habitats, values, threats, and status was recorded using the guidelines in Tables 2.3 and 2.4 and in the formats in Table 2.5 to 2.9.

The organism/species data formats were based on the five Kingdoms of living things namely: Animalia, Plantae, Fungi, Protista, (Protozoa) and Monera (Bacteria). The Kingdoms were sub-divided into a seven taxonomic categories (Kingdom, Phylum / Division, Class, Order, Family, Genus and Species). The common name of the taxa/organism/species was where never possible recorded. Data collection focused on the kingdoms Animalia, Plantae and Protista for which data was available. Data collection in the kingdom Animalia concentrated on the classes comprising fishes, amphibians, reptiles, birds, mammals and invertebrates. Aquatic macrophytes were examined in the Kingdom Plantae and Algae in the Kingdom Monera.

The data formats for genetic diversity in addition to capturing data under species diversity captured some data on genetic variability.

Table. 2.3. Guidelines for data collection under ecosystem, organism/species and genetic diversity

Major aspects provided in the ecosystem and organism/species tables
Country – Name of Partner State (Kenya, Uganda, Tanzania, Rwanda, Burundi)
Ecosystem category – Name of the ecosystem category (Lake, river, wetland)
Ecosystem Names – Name of the ecosystem (e.g. Victoria, Nile etc)
Location – GIS location of the ecosystem
Areas/length – Area of ecosystem in case of lake or wetlands and length for rivers
Depth – Depth of the lake
Water discharge – water discharge for river
Taxonomic category (classification of the organism/species from Kingdom to class)
Common name (common Name of the taxa e.g. Nile perch)
Habitats – the normal habitat of the organism/species (see examples of habitats below)

Major aspects provided in the ecosystem and organism/species tables
Country – Name of Partner State (Kenya, Uganda, Tanzania, Rwanda, Burundi)
Values – values of ecosystem/species (see examples values below)
Threats – threats to the biodiversity category (see examples of threats below)
Trends – changes in ecosystem, species, values, threats over time – this was given in detail under the trends table
Status – this was obtained from the trends in ecosystem and species parameters – also see IUCN classification (see the IUCN illustration of determining threats)
Gaps – this represented situations where critical biodiversity information and data was missing
Other aspects considered – these were given as notes where necessary
Information on critical habitats/ecosystems and biodiversity hot spots
If the species is endemic, is an indicator species, is protected, flagship species, keystone species
Conservation status of threatened ecosystems/habitats, species *in situ* and *ex situ*
The area and distribution of conservation areas and changes in area and distribution of conservation areas
Currents efforts to manage threats of ecosystems/species

Table 2.4. Guidelines for assessing habitats, values, threats and status

Habitats:		
Inshore [IS]	Muddy bottom [MB]	Pelagic zone [PZ]
Offshore [OS]	Rocky areas [RA]	Widespread [WS]
Macrophyte zone [MZ]	Littoral zone [LZ]	Fast flowing waters [FW]
Sandy bottom [SB]	Benthic zone [BZ]	River mouth
Values:		
Human food [FH];	Scientific [SC]	Water supply [WS]
Aquatic food-web [AF]	Ecological [EC]	Fishing [FS]
Medicinal [MD]	Keystone / flagship species [KS]	Hydropower generation [HG]
Handcrafts [HC]	Employment [EM]	Transport & communication [TC]
Construction materials timber, grass, sand, clay [CM]	Export earnings [EE]	Tourism and recreation [TR]
Agricultural / Aquaculture [AG]	Energy source [ES]	Environmental [EV]
Threats:		
Habitat loss [HL]	Over-exploitation rates [OE]	Pollution / Eutrophication [PE]
Invasive Alien species [IA]	Climate change [CC]	
Status:		
Extinct [EX]	Extinct in the Wild [EW]	Endangered [CR]
Critically Endangered [EN]	Vulnerable [VU])	Near Threatened [NT]
Least Concern [LC]	Data Deficient [DD]	Not Evaluated [NE]

Diagrammatic illustration of IUCN criteria for determining threats to biodiversity

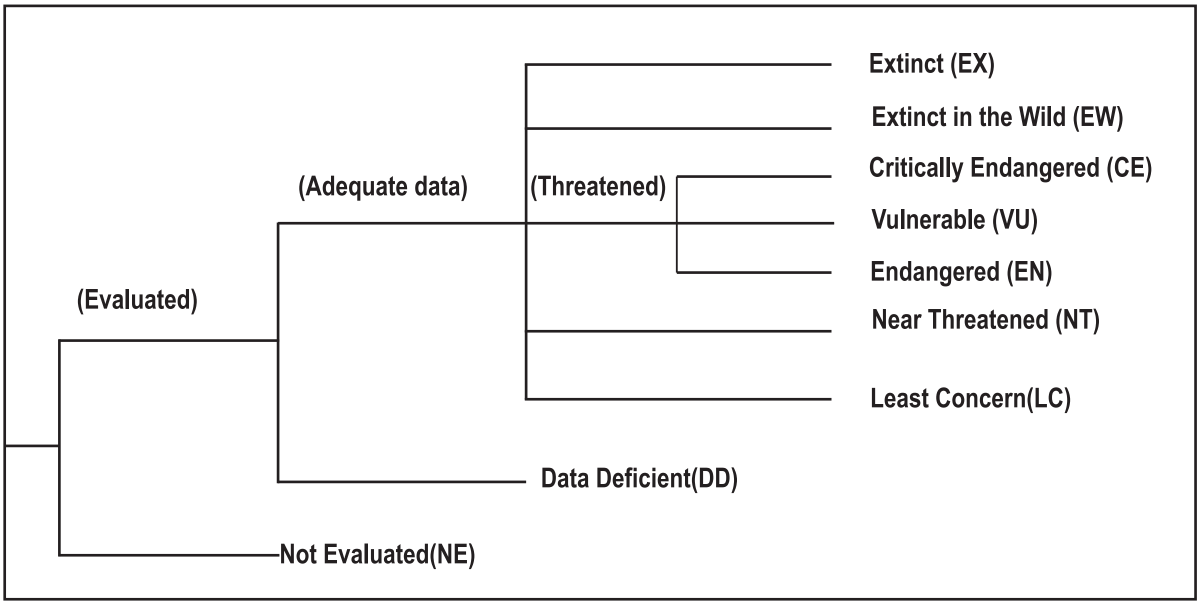

Table.2.5. Data formats for ecosystem diversity

Country	Ecosys-tem Category	Ecosys-tem Name	Location	Area / length Depth	River discharge	Values	Threats	Trends	Status	Gaps	Data Source

Table.2.6. Data format for trends in ecosystem parameters

Time (Year)	Name of ecosystem	Ecosystem parameter 1	Ecosystem parameter 2	Ecosystem parameter 3	Ecosystem parameter 4	Ecosystem parameter 5 etc.

Table.2.7. Data format for organism/species diversity

Country	Ecosystem category	Ecosystem Name	Kingdom	Phylum / Division	Class	Order	Family	Genus	Species	Common name	Pic	Habitats	Values	Threats	Trend	Status	Gaps	Data Source
	Lake	Victo-ria	Animalia	Chor-data	Fishes	Dipnoi	Lepidosireni-dae											
						Isospondyli	Mormyridae											
						Percomorphi	Centropomo-dae	*Lates*	*niloticus*	Nile perch								
						Opisthomi	Mastecembali-dae											
					Amphibians													
					Reptiles													
					Birds													
					Mammals													

Country	Ecosystem category	Ecosystem Name	Kingdom	Phylum / Division	Class	Order	Family	Genus	Species	Common name	Pic	Habitats	Values	Threats	Trend	Status	Gaps	Data Source
				Inverte-brates														
			Plantae		Macrophytes													
			Protista (Protozoa)	Algae														

Table 2.8. Data format for trends in organism/species diversity

Time (Year)	Name of ecosystem	Organism/Species parameter 1	Organism/Species parameter 2	Organism/Species parameter 3	Organism/Species parameter 4	Organism/Species parameter 5 etc.

Table.2.9. Data formats for genetic diversity

Country	Ecosystem category	Ecosystem name	GPS location	Genus	Species	Common name	Processing Labora-tory	Depot of un processed tissue	Representative specimen/form	% polymorphic Loci	Genetic distance	Genetic diversity	Heterozygosis estimates	No. of unique alleles	Values	Threats	Trends	Status	Gaps	Data source

2.3. Data Formats for Socio-Economic Values

The data formats for socio-economic values captured data on the country, biodiversity category, the resources or benefits or services derived from the biodiversity category, the production quantities, the production values, the export quantities and export values as in Table 2.10 and 2.11.

Table 2.10. Data formats for socio-economic values

Country	Ecosystem Category	Ecosystem Name	Resources	Activities	Products/ Services
Uganda	Lakes	Victoria	Water	Water supply	Water

Table. 2.11. Data formats for socio-economic values

Resources/ Commodity	Products/ Services	Time/ Year	Production system	Production quantities	Production values	Export quantities	Export values

2.4. Data formats on Policy and Legislation

The data formats on legal instruments captured information on coverage (international, regional or national); the title of the legal instruments; the Summary provision; and remarks and recommendation indicating the level of compliance and any required actions and gaps or short comings as in Table 2.12.

Table 2.12. Data formats on legal instruments

Coverage & Institution	Title of Legal instrument & Date of adoption	Summary of provision	Remarks & recommendations	Data source

2.5. Data Formats on Institutions and Experts

The formats on institutions captures information and data on the name of the institution and the country where it is located; the umbrella status (whether research, management academic); the categories of the biodiversity data that it holds; the form in which the data is held (database, spreadsheet etc); the data management capacity (if there is adequate infrastructure and human resources capacity to manage the data); the data access policy and gaps in Table 2.13 and that on experts captures the information as in Table 2.14.

Table 2.13. Data format on institutions

Country	Institution	Umbrella status	Mandate	Categories of data	Databank & Form	Management capacity	Access policy	Gaps	Source

Table 2.14. Data formats on experts

Country	Name of institution	Name of expert	Position of expert	Address	Email	Telephone No	Biodiversity area of expertise

2.6. Bibliographic Data Formats

The format for bibliographic data is as in Table 2.16.

Table 2.15. Format for bibliographic data

Ref. No.	Author(s)	Year of publication	Title	Publisher & Place	Size pp

2.7. Data collection and analysis

The information and data was collected from national and regional institutions responsible for data on aquatic biodiversity within the LVB. These included: Fisheries Research Institutions (NaFIRRI, KMFRI, TAFIRI); Fisheries Management Departments/Divisions; Water Management Departments/Divisions; Universities; Wetland Management Departments/Divisions; National Environment Management Authorities; Wildlife Authorities, The National Museums of Kenya (NMK) etc.

The analysis involved: the socio-economic values of the different categories of aquatic biodiversity, the status of the different categories of biodiversity examined, policy, legal and institutional issues.

The status of the different components of biodiversity covered information and data on: status, values, threats, trends in composition; conservation and management efforts; gaps in information and data; some key facts on the aspects examined and conclusions and recommendations to reduce the threats and fill the gaps.

The numbers of ecosystems in each ecosystem category and the number of taxa/species under each taxonomic category was given in a table.

The trends were represented by the changes in key parameters of the biodiversity category, values, and threats over time and were presented graphically from which the status was arrived at.

The data formats developed were used to develop a meta-database.

3. THE STATUS OF AQUATIC BIODIVERSITY INFORMATION AND DATA

3.1. SOCIO-ECONOMIC VALUES OF AQUATIC BIODIVERSITY

3.1.1. Introduction

The socio-economic review examined the information and data available on the values of the aquatic biodiversity within the basin and their implications for social, cultural and economic development within the region. Value refers to the importance of the biodiversity component, based on the benefits and services it generates, contributing to the goals of poverty alleviation, employment, nutrition and health as well as foreign exchange earnings as well as ecosystem services. Values may be applicable at the community, national, regional or global levels. They may be qualitative or quantitative, expressed in monetary units. They may be stocks or flows, with the latter being preferred for their usefulness.

The components of aquatic biodiversity examined in this study included ecosystems (lakes, rivers and wetlands), the organisms in these systems comprising aquatic macrophytes, algae, invertebrates, fishes, amphibians, reptiles birds and mammals.

Biodiversity values fall within four categories:
i) direct use values;
ii) indirect use values;
iii) option values ; and
iv) existence values.

Direct use values refer to the benefits people derive their livelihoods from exploitation of the biodiversity to produce goods and services, supplying local consumers, industrial processors and export markets.
Indirect use values refer to the ecosystem services provided.
Option values reflect the desire among people that the biodiversity should not be destroyed by its present use but should continue to provide benefits of the same quality in the future at undiminished rates.
Existence values refer to the satisfaction people gain from simply knowing that a biodiversity element exists although they do not personally obtain any direct or indirect goods or services from it.

3.1.2. Direct use values:

Direct use values derived from the ecosystems and species within the LVB include water supply, navigation, tourism and recreation, plant resources, mining and industries. These values contribute to poverty alleviation, employment, health and nutrition.

i) *Water supply*

The three aquatic ecosystems categories in the LVB (lakes, rivers and wetlands) are important sources of water. They provide water for domestic use, including drinking, cooking, bathing and washing, and farm usage. Urban centers within the basin draw water from the lakes and rivers. These include the cities of Kampala, Kisumu and Mwanza as well as towns such as Jinja, Entebbe, Bukoba and Homa Bay. A number of industries in the region also extract water from the lakes and rivers as a major raw material or coolant into their production processes. These include breweries, soft drink producers, food processors, fish processors, processors of hides and skins and the construction industry.

ii) *Navigation*

Lake and rivers are used for transportation of people and goods. Boats of different sizes ply the waters of the lakes and rivers, providing transport and communication between communities, across nations and also across borders of the Partner States. Port Bell, Kisumu and Mwanza are important harbors for regional shipping traffic. Water transport is considered to be low-cost, compared to road transport.

iii) *Hydro-electric power*

Some of the rivers are used for hydro-electric power generation. Notable examples are Kiira and Nalubaale dams located on the White Nile which generates 250 mega watts and the dam on River Sondu Miriu, which generates 62 mega watts. Other rivers in the basin have potential for hydropower generation and Lake Victoria serves as a reservoir for water for the White Nile.

iv) *Tourism and recreation*

The lakes and rivers provide tourism and recreational values. Museums are found at different centers in the region, exhibiting materials from the basin. Several resort beaches have been built on Lake Victoria as part of tourism in the region, taking advantage of its scenic views. Eco-tourism is also an increasing industry in the region. Different water sports take place on the water bodies, including sailing and canoe racing. Sport fishing and bird watching are also carried out. Cottage industries are established to produce tourist products. However, tourism is hindered by poor transport and communication in parts of the region.

Ornamental products are made from the various plant and animal organisms and are kept by diverse institutions such as schools, households and hotels. Notable among these are the colorful haplochromine species which are used in the aquarium trade.

v) *Nutrition and health*

The three ecosystems are sources of food, as different edible organisms are produced from them. These range from algae, invertebrates, fish, non-fish animals to plants. The wetlands are important for agriculture, involving production of rice, yams, sweet potatoes, maize, cassava, beans and vegetables, among other crops. Significant rice schemes are found on Kenyan rivers of Sondu, Nzoia, Yala and Nyando.

Fish is the most important source of protein in the basin and a wide range of indigenous and introduced species are consumed by the local communities, the most important being the Nile perch, tilapia and dagaa. LVFO estimated fish production from Lake Victoria at 970,000 tonnes in 2006.

Some fish species are valuable as medicine e.g. the haplochromines widely used in treatment of measles. Others are important biological control agents of certain disease vectors e.g. *Astatoreochromis alluaudii* that was widely used in the basin as a control to snail vectors and *Gambusia sp* for control of malaria vectors.

The ecosystems are also sources of medicinal values, particularly from the various plants with medical properties. These plants are frequently used to treat a wide range of diseases, including cough, headache, intestinal worms, malaria, chest pain, gonorrhea and impotence, to mention just a few.

However, the ecosystems also harbour vectors of human and livestock diseases and are, therefore, of public health concern. Malaria, bilharzias, dysentery and other water borne diseases are prevalent throughout the lake basin.

vi) *Cultural values*

Cultural values of different types are derived from the lakes, rivers and wetlands. Several sites on these water bodies are used as shrines for cultural activities as many gods and spirits are believed to reside in these ecosystems. Recent reports talk of under-water rituals which allegedly bring wealth to the beneficiaries. Some fish species have cultural and spiritual values, including identity, heritage and inspiration. An example is the lung fish, which is the identity for the 'mamba' clan among the Baganda.

vii) *Handicrafts*

Handicrafts, packaging, mats, pots, baskets, fish smoking materials, fencing, fish traps and floats are some of the valuable common products made from aquatic ecosystem materials especially wetlands. The materials include papyrus, reeds, spear grass, nappier grass, elephant grass, Typha and shrubs. The annual income from harvesting papyrus within the basin in Uganda is estimated at US $ 320 million.

viii) *Industries and exports*

Raw materials for industries are another form of value from the ecosystems. A notable example is that of the Nile perch wish goes through industrial processing to produce chilled fillets, frozen fish and other by-products for export as well as domestic markets. Dagaa (omena or mukene) is also used in feed production. Cottage industries draw raw materials such as papyrus, grass and water hyacinth for making crafts.

Exports, which generate foreign exchange earnings for the Partner States, constitute another form of value from the aquatic biodiversity. The main products exported here include frozen and chilled fillets and selected by-products of Nile perch, sun-dried dagaa, as well as several crops which are traded across the regional borders. The quantity of Nile perch fillets exported from Lake Victoria increased from 20,000 tonnes valued at US$ 27 million in 1992 to 86,000 tonnes valued at at US$ 313 million in 2006. The contribution of fish to GDP is 2% for Kenya, 2.8% for Tanzania and 3% for Uganda.

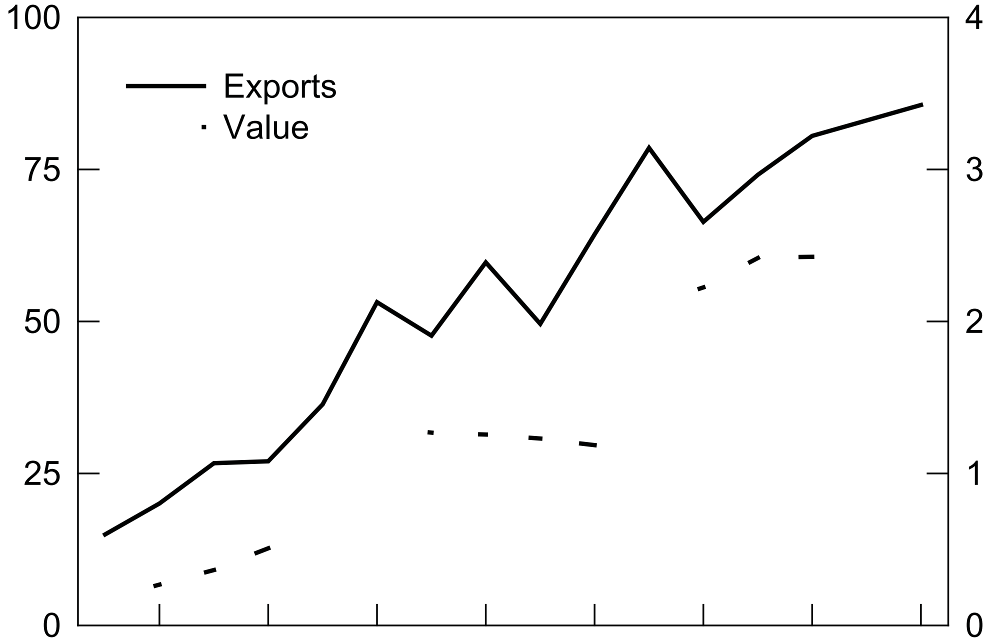

Figure 3.1.1. Trends in Nile perch exports ('000 t) and value (million US$) from Lake Victoria from 1991 to 2006

ix) *Construction and mining*

Construction materials for shelter obtained from biodiversity resources include spear grass, nappier grass, elephant grass, reeds and shrubs obtained from the lake shores, river banks and wetlands. Certain types of trees found in wetlands are also used in the construction of boats. Brick making and pottery involving soil excavation takes place mainly in urban wetlands, where construction activities are concentrated. Sand mining from lake shores, rivers and their deltas and wetlands is also concentrated near urban areas where construction is high. Available data suggest that an estimated UShs 134.6 million per annum is generated from brick making and UShs 586.9 million from sand mining in Murchison Bay in Uganda.

x) *Energy sources*

Energy sources, such as firewood, charcoal and briquettes, are values obtained from the plant organisms found in the ecosystems.

3.1.3. Indirect use values

Several components of aquatic biodiversity are also important for the indirect use values they provide, mainly through ecosystem services, namely climate modification, water purification, waste water treatment, flood control and water storage and distribution. They also have vital attributes such as biological diversity, gene pool research material and aesthetic values.

i) Phytoplankton (algae) are a vital basis for higher secondary production, including fish. Algae are, therefore the most important primary producer in lake ecosystems and they also probably the first living aquatic resource to directly manifest the effects of eutrophication. Excessive algae may cause fish kills while certain types of algae are toxic.
ii) Invertebrates are a vital resource in aquatic ecosystems as zooplankton is a major dietary

component in the early life of most young fishes. Some fish such as dagaa feed almost exclusively on it. Many zooplankton taxa are also algal grazers and, thereby, constitute a vital link between primary and higher production along the grazer food chain. Macro-invertebrates are also consumed by higher organisms, especially fish (e.g. dagaa, Nile perch and Nile tilapia). Occurrence of particular aquatic invertebrates may provide a biological indication on the environmental health of a given system.

iii) Fish are parts of integrated aquatic ecosystems driving key food web interactions. Thus, in addition to direct economic values, fish populations play active roles in the maintenance of aquatic ecosystems and in the provision of a range of ecosystems services either as prey or consumers of organic matter produced in the lakes.

iv) Reptiles are an important tourist attraction and varieties of reptiles are kept in zoos. They serve as biological indicators of the environment and some feed on rodents which could be destructive to man and his crops and others are edible by man.

v) Birds are a tourist attraction and bird watching is a major recreational activity. The high mobility of birds enables them to move away from unfavorable environments. The Lake Victoria region is a route for birds that migrate to the southern from northern hemisphere during winter. Changes in abundance and distribution of aquatic birds can give an indication of environmental health. For instance the presence and density of Marabou, *Leptoptilos crumeniferus* can give an indication of the poor refuse management of a town. Some birds like gulls and sterns feed on fish and their concentration provide fishermen with information of suitable fishing grounds. Birds are also able to return nutrients to lake ecosystems through deposition of the *Guano*, a nutrient rich form of urea.

vi) Water associated mammals like Sitatungas and Hippopotamus are hunted for meat and Sitatunga heads are used as trophies. Other aquatic mammals like Otters are important tourist attractions and are used as pets in zoos.

vii) Macrophytes play an active role in water and nutrient cycling and in climate moderation. They also help to regulate the carbon level in the atmosphere through photosynthesis, thereby acting as carbon sinks. They are therefore important for carbon sequestration. They provide micro-habitats for wildlife including fish.

viii) In addition to the role played by macrophyte species, the wetland ecosystems provide values in different ways. Several urban and rural communities draw their water supply for domestic use from wetlands. Soil from wetlands is used for brick making as well as smearing and decorating houses by the local communities. Wetlands are often used as farmland, producing certain crops which are suitable for these conditions. They are a source of food, as many wetland plants are edible either as fruits or leaves. Wetland fish species are valuable sources of food. Other wetland plants have medicinal values and are used in the treatment of a wide range of common diseases. Papyrus, reeds, grass and shrubs from the wetlands are used for construction of shelters by local communities while clays are used in brick making. The macrophytes are also used in making crafts, in packaging of fish as fuel wood. There is potential for eco-tourism within the wetlands.

ix) Riverine ecosystems significantly contribute to the water budget of Lake Victoria. The rivers drain and dissect catchments in the entire region and contribute to climate modulation and soil fertility for agricultural production. Due to the diversity of habitats associated with altitude, gradient, water flow patterns, and soils in addition to the vegetation, the riverine ecosystems support diverse bird, animal and fish communities of ecological and economic importance. In addition, the flood plains are important as seasonal livestock grazing areas and fishing grounds.

x) Genetic diversity is of value because its protection and conservation maintain health population diversity and longer-term viability. Fish genetic resources contribute to the performance of farmed fish and their interactions, including genetic interactions, with aquatic biodiversity. In capture fisheries fish genetic resources can determine the productivity of fished populations and their adaptability to environmental change including climate change.

3.1.4. Option values

Communities and nations attach option values to biodiversity, reflecting the desire that the biodiversity should not be destroyed by its present use but should continue to provide the same benefits for future generations. This sustainability is achieved through management. In the case of fish, a management system has been established for the sustainable exploitation of the fisheries of Lake Victoria. During the last Fisheries Management Plan (2004-08) an estimated € 29 million grant from the EU was utilised to manage the fisheries resources. Similarly, investments have been made in the protection of wetlands, river banks and assorted institutions.

However, budgets for management of wetlands, rivers and the smaller lakes in the basin, which would indicate the option values for the ecosystems, are not readily available and need to be compiled. Furthermore, there are no management systems in place and related budgets for sustainable utilisation of most of the species biodiversity, and this constitutes a major gap in the information.

3.1.5. Existence values

There is much less information on the existence values of aquatic biodiversity within the basin. However, cultural heritage values are attached to the lakes, rivers and wetlands in the basin by the communities and Partner States but no studies have been carried out to quantify existence values.

3.1.6. Human impacts on biodiversity

Human activities affect the aquatic biodiversity in several ways however, often; it is the cumulative impacts that can manifest changes in biodiversity and its values. The major human activities affecting biodiversity in the LVB are:

i) Urbanisation and industrial development may lead to pollution of the aquatic systems.
ii) Reclamation of wetlands for agricultural and industrial purposes may result in frequent flooding, destruction of biodiversity habitats and adverse local climate modification characterised by prolonged droughts.
iii) Slash-and-burn agriculture may lead to biodiversity loss.
iv) Farming on river banks and at the edge of lakes and wetlands may lead to siltation of the water bodies.
v) Over-fishing and use of destructive fishing gears and methods may lead to collapse of the fisheries.
vi) Damming of rivers for electricity generation may lead to floods within the river basin.

vii) Excessive extraction of water for irrigation and other purposes may lead to a fall in water level, resulting in water shortages.

3.1.7. Equity

Biodiversity resources are common property resources which should be utilised for the common good of the people. However, there is no mechanism for ensuring that there is equitable sharing of the benefits from the genetic and other biodiversity resources among the Partner States and the riparian communities. These disparities are attributed to unequal distribution in production assets such as capital, skills and credit, poor access to market and inadequate policies to deal with income disparities.

3.1.8. Threats to biodiversity values

Biodiversity values are threatened as a result of human activities in relation to their utilization. This may take the form of excessive exploitation beyond the carrying capacity or through the use of destructive extraction gears and methods. Among the most threatened resources are the fish and this is attributed to the growing population and increased demand for fish for domestic consumption and for export.

Industries generally pose a risk to the ecosystems though pollution, resulting from direct discharge of organic waste, detergents, caustic soda, oils, lubricants, chlorine and dyes with little or no treatment.

3.1.9. Information and data gaps

There is inadequacy in data on the different values of most of the lakes, rivers and wetlands because most of the activities are carried out on subsistence basis through informal organizations. The values and trends of most biodiversity resources are not documented.

3.1.10. Conclusions and Recommendations

The following recommendations should be implemented to improve the understanding and quantification of the values from the aquatic biodiversity in the basin:

i) Carry out studies of utilization and quantities of water from the different aquatic ecosystems.
ii) Monitor the patterns of navigation on the lakes and rivers and the volumes of traffic for goods and passengers.
iii) Monitor production and marketing of the less significant fish, including riverine and wetland species.
iv) Study the structure and volumes of tourism and sports on the aquatic ecosystems including ornamental fisheries.
v) Carry out studies of the cultural uses of lakes, rivers and wetlands by the local communities.
vi) Carry out studies of potential and actual exploitation of hydro-electric power from the rivers within the LVB.
vii) Monitor utilization of wetland resources in the crafts, packaging and construction industries.
viii) Study management systems for the utilization of the different biodiversity resources.
ix) Studies to quantify indirect use, option values and intrinsic values should be conducted.

3.2. LAKE ECOSYSTEMS DIVERSITY IN THE LAKE VICTORIA BASIN

3.2.1. Introduction

Freshwater aquatic ecosystems diversity can be subdivided into three broad categories namely: lakes, rivers and wetlands. In the Lake Victoria Basin (LVB) in Eastern Africa, some of the ecosystems (e.g. Lake Victoria, River Kagera, River Sio, River Nile) are trans-boundary while others completely fall within defined national boundaries of the East African Community (EAC) Partner States (Kenya, Tanzania, Uganda, Rwanda and Burundi). The LVB ecosystems share common geographic characteristics and origin and a drainage structure that links them through diverse climatic and ecological functions and processes. For example, the basin is made up of the main lake itself and numerous satellite lakes associated with wetland and river systems.

3.2.2. Categories of lake ecosystems

Lake Victoria Basin is home to one of the world's most remarkable aquatic ecosystems that supports a tremendous abundance and diversity of life. The lake and its basin have played a major role in the history and development of East African inter-lacustrine region. Despite the role of biological diversity as the basis for the functional integrity and socio-economic values of the Basin, aquatic biodiversity conservation planning efforts have rarely targeted it. As a result, aquatic biodiversity is more imperiled than its terrestrial counterpart, partially because synthesized and comprehensive data on the distribution of biodiversity is lacking.

Lake Victoria located in the upper reaches of the Nile River Basin, spans a catchment area of 194,000 km^2 in five countries Uganda, Kenya, Tanzania, Rwanda, and Burundi. Mountains surround the catchment area on all sides except the north. The main islands within the lake include the Sesse or Kalangala and Buvuma in Uganda; Ukerewe in Tanzania and the Rusinga in Kenya. The basin has an equatorial climate, with relatively high mean annual rainfall of 1200-1600 mm. To the north of the lake, there are two rainy seasons; one during March/May, and the other during October/November, whereas the south experiences one long rainy season from December to March. Temperature of the lake varies from 23-27°C with a mean temperature of 25°C throughout the year and this small difference plays a role in the lake's limnology. Wind speed is generally low during the wet season (0-3.5 m/s), due to the protection of the Rwenzori mountains in the north and the Rift escarpment to the east and south. Low wind speeds allow for the build up of a thermocline, which results in stratification of the lake.

Lake Victoria is the largest tropical lake (68,800 km^2) in the world as well as the second largest freshwater lake in the world, occupying a shallow depression 1,134 m asl, between the west and east African rifts, stretching 412 km from north to south and 355 km from west to east and spans the borders of Tanzania, Uganda and Kenya. The water balance of Lake Victoria is maintained primarily through rainfall and evaporation, rather than inflows and outflows. Due to the dependence of the water balance on rainfall and evaporation, the residence time of water in Lake Victoria is 21 -23 years. The water level of Lake Victoria has varied by about 2 meters in the last century in response to changes in rainfall and evaporation.

Table. 3.2.1. Major characteristics of the Lake Victoria Basin (surface area, shoreline and basin area, population and population density in the LVBC countries).

Country	Lake surface		shoreline		Basin area		Popn (million people)	Population density (No. of people/km²)
	km^2	%	km^2	%	km^2	%		
Kenya	4,113	6	550	17	38,913	22	12.5	321
Tanzania	33,756	49	1,150	33	79,570	44	5.6	70
Uganda	31,001	45	1,750	50	28,857	16	5.6	194
Rwanda	0	0	0	0	20,550	11	6.9	336
Burundi	0	0	0	0	13,060	7	4.1	313
Total	68,870	100	3,450	100	180,950	100	34.7	

Lake Victoria experiences annual stratification and overturn with an associated upwelling of nutrients. Wind speeds increase during the dry season, between May and June when strong southerly winds exceeding 15 m/s blow over the basin. These strong southerly winds cause high evaporation rates, water mixing and a decrease of surface temperatures. Seasonal algal blooms coupled with shallow water upwellings as a result of wind action, affect seasonal transparency patterns in the lake.

Table 3.2.2. Characteristics of the Lake Victoria Water Balance

Characteristic	Measure
Position: Latitude	0^0 20' – 3^0 00'S
Longitude	31^0 39' – 34^0 53' E
Altitude (m above sea level)	1134
Catchment area (km^2)	194,000
Lake basin area (km^2)	68,800
Lake area as % catchment	37
Shoreline (km)	3,440
Max. length (km)	412
Max. width (km)	355
Mean width (km)	172
Max. depth (m)	84
Mean depth (m)	40
Volume (km^3)	2,760
Inflow ($km^3 .yr^{-1}$)	20
Outflow ($km^3 .yr^{-1}$)	20
Precipitation ($km^3 .yr^{-1}$)	114
Annual lake level fluctuations (m)	0.4 – 2.0
Max. rise in lake level (m)	2.4
Flushing time (years)	138
Residence time (years)	21

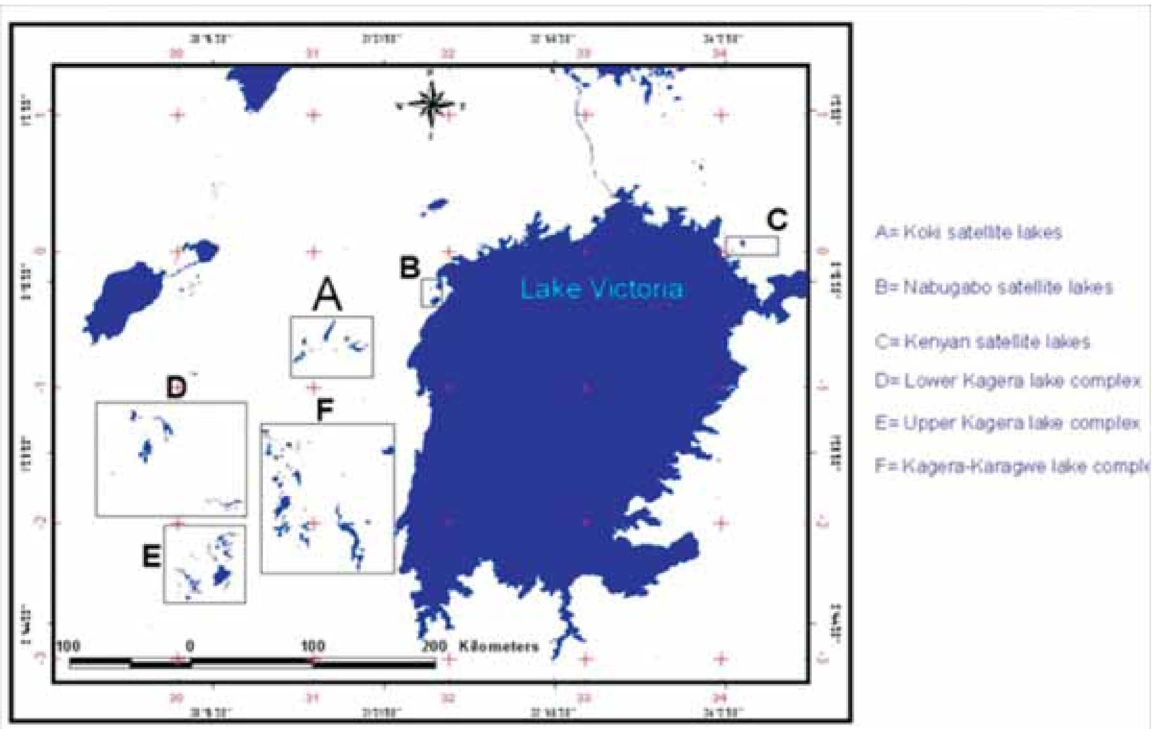

Figure 3.2.1. Lake Victoria and surrounding satellite lakes in the Victoria basin

There are about 50 satellite lakes that are geologically and ecologically related to the main lake. Koki and Nabugabo satellite lakes in Uganda, Kenyan satellite lakes, Lower Kagera satellite lakes, Upper Kagera satellite lakes, and Kagera Karagwe lake complex (Fig. 3.2.1).

The Koki complex lakes include Kachera, Mburo, Kijanebalora connected to each other by extensive papyrus swamps. The sizes and shapes of the lakes themselves vary from year to year. These lakes still contain populations of *Oreochromis esculentus* that has disappeared in the main lake.

The Nabugabo lakes include Nabugabo, Kayugi, Kayanja and Manywa. These lakes are drained by Rivers Juma, Kagona, Kikoma and Nzonsemu. Lake Wamala is located within the basin north of the Nabugabo lakes.

Kenyan satellite lakes include Kanyaboli, Sare, Nambayo and Simbi but there are also large reservoirs such as Ulanda, Ufinya, Koriga, and Migowa, which provide aquatic biodiversity habitats.

The upper Kagera lakes complex in Rwanda and Burundi are distributed as Ingitamo, Gacamurinda, Kanzigiri, Lirwihinda, Rungazi and those in Rwanda are Birira, Gaharwa, Gashanga, Kidogo, Kirimbi, Mirayi, Mugesera, Muhazi, Murago and Sake etc. Lakes Cyohoha South and Rweru are shared between the two countries.

Lakes Chuju, Hago, Ihema, Iwapibali, Kishanja, Kivumba, Mihindi, Muhari, Nasho, Ngerenke, Rukira, Rwakibare, Rwampanga, Rwanyaki Zinga, Rwehikama, Sekena are found in Rwanda and Lakes Bisongo, Kajumbura, Lwelo, Mujunju, Rushwa, Burigi and Ikimba are found in Tanzania in the lower Kagera region.

Most of these lakes are shallow and are surrounded by wetlands which play an important role in stabilizing their water regimes. They in turn assist in stabilizing the water regime of associated rivers and the main lake. Their protection is therefore vital to stabilization of water in the rivers and the main lake. The lakes may are also valuable sources of biodiversity and act as refugia for many species of fish that have disappeared from the main lake. They are therefore important reservoirs for endangered fish species of Lake Victoria. Some of these satellite lakes are close to pristine conditions and have been protected from Nile perch invasion by wetland buffers. Most of the satellite lakes are surrounded by macrophytes, mainly papyrus and some are not easily accessible.

3.2.3. Threats to lake ecosystems

The main threats to the lake ecosystem include: excessive extraction of water, pollution, excessive input of nutrients and contaminants and sewage resulting into eutrophication and anoxia.

Over the last 40 years, water pollution has become a serious threat resulting into eutrophication and associated deoxygenation, radically changing the environmental state from mesotrophic to eutrohic conditions. Consequently, the lake has experienced a serious decline in water quality since the 1960's i.e. Total phosphorus concentrations have increased by a factor of two, algal biomass by a factor 8 to 10.

The central part of the lake has low Total Suspended Matter (TSM) while in areas where rivers enter it have high quantities e.g. in Winam Gulf, Speke Gulf, north-western part of the lake. Data over last four decades demonstrate eutrophication trends in the near-shore zones of Lake Victoria especially in inshore waters of Napoleon Gulf, Winam Gulf and the open waters near Bugaia Island.

The lake's water level variations, derived from satellite altimeter measurements, show a negative height variation trend—even after the significant inflows of water from the 1997-98 flooding. Current water levels in Lake Victoria are below normal and the lowest level since September 1961. This pattern is now a long-term concern to all the countries in the basin, as well as those along the Nile Basin.

The post 2002 regime has tended towards the pre 1961 regime (Fig.3.2.2). The period 2002 to 2005 indicated rapid and worrying decrease in Lake Victoria water level and it is the main course of the present concern. During the same period, annual rainfall decreased over the years (Fig.3.2.3). Water temperature records from the 1950s to 2005 show an increase of 1ºC, however, evaporation from the Lake has remained rather stable.

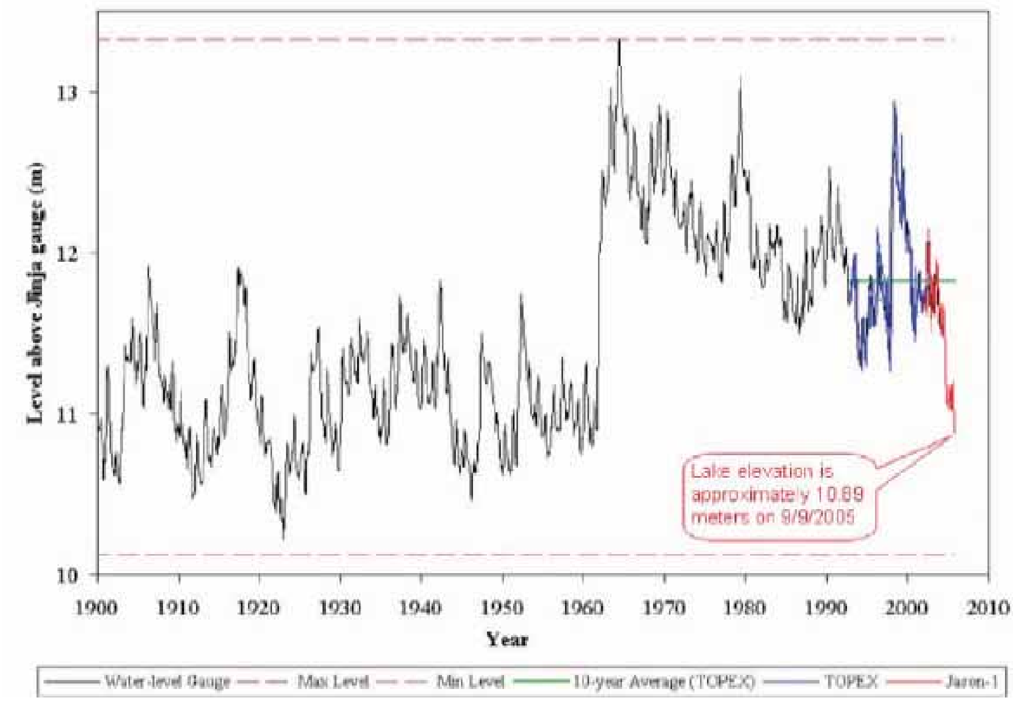

Figure 3.2.2. Historical water level gauge data from Jinja (near Lake Victoria outlet). Satellite radar altimeter data from U.S. Department of Agriculture (USDA)/Foreign Agricultural Service (FAS)/Production Estimates & Crop Assessment Division (PECAD). Source:http//www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

Available data shows that there has been an overall total decline in catchment inflows into Lake Victoria of 22 % in the last 5 years from 2000. The Kagera river yield alone has declined by over nearly 10 % of its relative catchment contribution.

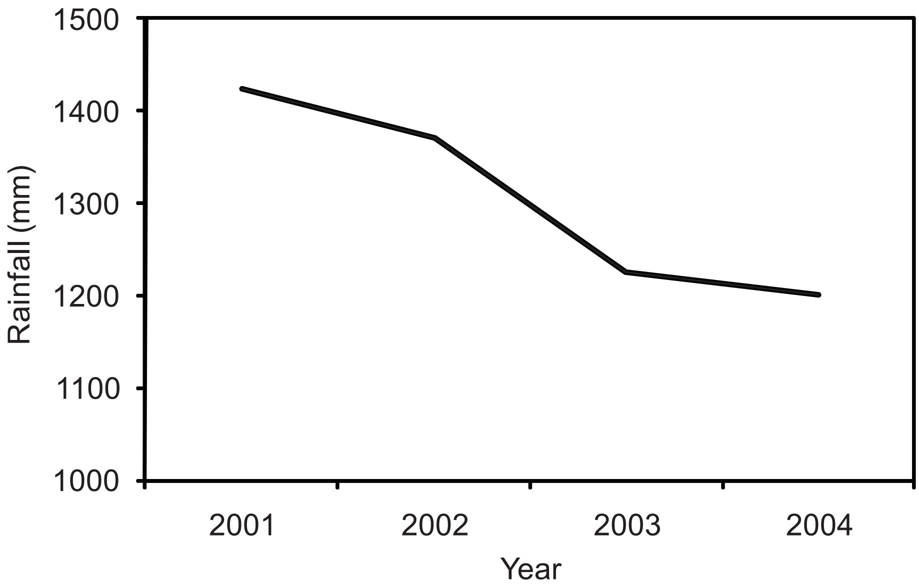

Figure 3.2.3. Changes in annual rainfall from 2001 to 2004.

The water balance of the lake has as a result of moderate changes in rainfall over the lake and in the catchment hydrology changed during the period 1950-2000 compared with the period 2001-2004 (Table 3.2.3).

Table 3.2.3. Summarized water balance of Lake Victoria for the periods 1950-2000 and 2001-2004.

Process	1950-2000 Flow m^3/s	%	2001-2004 Flow m^3/s	%
Inflow				
i) Rainfall	3611.5	81.8	3644.0	84.2
ii) Basin discharge	805.3	18.2	686.2	15.8
Outflow				
iii) Evaporation from lake	3329.8	76.1	3337.5	73.5
iv) Victoria Nile	1046.2	23.9	1,201.9	26.5
Sum	**40.8**		**-209.2**	

Apart from a drastic decline in the fisheries and deterioration of the water environment, forests in the catchment are being rapidly cleared with approximately 45% of the land prone to soil erosion in many parts of the basin.

The main sources of excess nutrients, which cause serious eutrophication in near-shore environments around the lake are run-off from urban centers (e.g. Kisumu, Kampala, and Mwanza) and lakeside settlements, release of untreated or insufficiently treated municipal and industrial sewage. However, atmospheric deposition which may originate from distant or nearby locations is also an important source of phosphorus and nitrogen loads entering Lake Victoria. Management of this nutrient source by a single nation or region may therefore not be effective.

The threat of eutrophication due to nutrient enrichment, particularly with nitrogen and phosphorus affects the ecology and productivity characteristics of aquatic ecosystems which consequently results into excessive growth of phytoplankton, macrophytes, and weeds which as they decompose, impair water quality (cause low dissolved Oxygen, high turbidity, production of toxic gases such as hydrogen sulphide). Apart from eutrophication, the other major impacts on Lake Victoria include diversions, invasive species, land-use change, over-exploitation of resources, and pollution. The lake being very big and having major losses through evaporation, it has a high a potential to accumulate pollutants, which can be difficult to remove due to the long flushing time (Table 3.2.2). Lake levels of the lake are prone to climatic changes due to high losses through evaporation. Current lake levels appear to have resulted from climate change impacts.

The increased nutrient input to the lake has resulted in a decrease in the volume of oxygenated water and available fish habitat. Invasive species such as water hyacinth are a major problem in Lake Victoria Basin, and eutrophication associated with land-use change and overexploitation of resources is a growing problem.

3.2.4. Gaps in information and data on lake ecosystems

Data on the open waters and lake bottoms and many of the satellite lakes is so limited which highlights the need for a more complete biological inventory of the Lake Victoria Basin ecosystem as a whole.

3.2.5. Recommendations to reduce threats and fill gaps in data on lake ecosystems

Most of the research on lake ecosystems has been conducted on Lake Victoria, thus there is need to collect data on the satellite lakes.

There is need to regulate the release of water from the main lake to avoid the negative impacts of the decline in water level. This also calls for proper management of the satellite lakes, the wetlands and regulated withdrawal of ground water which assist in stabilizing the lake level. In addition, it is essential to identify the various sources of contaminants that pollute the waters of the lake and to control both point and non-point sources and to manage introduced flora and fauna especially water hyacinth.

3.2.6. Facts about the LVB lake ecosystems

a) Lake Victoria is the main geographic feature in the Lake Victoria Basin in terms of size, volume, fisheries and biodiversity values. The lake with an area of 68,800 km^2 is the second largest freshwater body in the world.

b) An estimated annual Gross Domestic Product (GDP) of US $ 30 billion is provided from Lake Victoria for about 30 million people its the basin, one of the most dense and poorest rural population in the world.

c) Socio-economic and ecological benefits from Lake Victoria bear on the premise that:
   i) It is the largest inland water fishing sanctuary in Africa
   ii) it is a major inland water transport linkage for Kenya, Uganda and Tanzania.
   iii) it is a source of water for domestic, industrial and commercial purposes
   iv) it is rich in biodiversity
   v) it is a major climate moderator in East and Central Africa

The socio-economic significance of the lake catchment on the other hand, is derived from its vast resources such as wildlife, forests and minerals which together with fertile soils sustain the main economic activity of the region-Agriculture.

d) There are numerous much smaller satellite lakes within the Lake Victoria Basin which are geologically and ecologically related to the main lake and to a large extent they share similar plant and animal communities along the evolutionary lines. The satellite lakes are ecological reservoirs of many fish species e.g. *Oreochromis esculentus* that have disappeared in the main lake.

e) The quality of water in the basin is major challenge whose main issues include:
   i) nutrient enrichment and eutrophication;
   ii) wise use of wetland buffers;
   iii) overexploitation of fish stocks;
   iv) invasive species introductions;
   v) coordination of research effort and information exchange; and
   vi) community participation in resource planning and management trends.

Monitoring of water quality is essential for effective management of the lake because clean and abundant water are requisites for the quality of life we all enjoy and business.

3.3. RIVERINE ECOSYSTEMS IN THE LAKE VICTORIA BASIN

3.3.1. Introduction

Riverine ecosystems are best defined as running water natural systems as opposed to enclosed water bodies such as lakes where water is more or less static. Rivers have longitudinal profiles characterized by steep slopes near the source of the river to minimal slope near the mouth. A subdivision can be made between inflow and outflow systems. Due to geographic features of a region, river flow alternates through a succession of types of water course ranging from the generally upstream fast-flowing rocky reaches to slow-flowing muddy and sandy stretches towards the mouths of the rivers. The upper stretches near the source of a river are characterized by faster flow, lower temperatures, higher oxygen concentrations with rocky, or gravel to sandy beds. A zonation of habitat types from upstream integrates into the lower stretches of river habitats as it flows towards its mouth with slow flow, higher temperature, and lower oxygen concentrations with mainly sandy and muddy beds.

3.3.2. Composition of river ecosystems

There are many inflowing rivers to Lake Victoria and its satellite lakes but only one major outflow the River Nile. The inflowing rivers and streams contribute about 18% of the water to the lake. River Nile contributes about 24% of the outflow. Kagera River (about 600 km long) is the principal inflow, which enters the lake along its western shore, draining the highlands of Burundi and Rwanda. Ruvuvu River is its main tributary. A series of swamps (2-18 km wide) and small lakes occur along the course of the Kagera River with several water falls in its upper reaches. River Nzoia enters the lake in the northeast, draining the Elgon Massif, the Cherangani Hills and Sergoit. Inflows from rivers in the northwestern and southeastern portion of the basin constitute the remainder of the riverine input. Apart from the Kagera and Nzoia, other major inflowing rivers include Mara, Yala, Sondu-Miriu, Nyando, Katonga and Kujja. Most of the inflows tend to be associated with several tributary streams and wetlands particularly in their lower stretches. Rivers entering the lake from the northeast tend to be swift flowing whereas; rivers of the northwest tend to be sluggish. Both the lake's shoreline and the main inflowing rivers are further characterized by often unrecognized numerous tributary first to third order streams and annual fluctuations in water level ranging from floods over extensive flood plains to streams that may dry up during the dry season.

3.3.3. Threats to riverine ecosystems

Threats to rivers to river ecosystems are primarily due to human-induced changes either in the river basin and/or in the river channels. Excessive land use through removal of riparian vegetation and a general reduction in basin land cover – forests, wetlands along river banks have led to increased run off resulting into a change in river hydrology and an influx of silt, nutrients and other dissolved substances. The impact may be accentuated by use of chemicals.

Within river channel changes are caused by dams and impoundments as well as direct resource exploitation. Dams and impoundments are used to store water for hydropower generation, flood control, for irrigation and for urban and industrial use. However, the net effect is to release water unnaturally and more slowly downstream leading to a change in flow characteristics as well as a reduction in flooded areas. Riverine populations are cut off from their migratory routes as new habitat conditions are created behind the barriers. In addition, altered flood plain conditions may not favour those aquatic fauna and flora which were adapted to the flood plain conditions for breeding, grazing, nurseries and aestivation. Other flood control measures on the flood plain may act in parallel as dykes are constructed along river banks to protect human settlements from flooding or to develop floodplain agriculture e.g. rice and sugarcane.

Changes in physico-chemical conditions in riverine ecosystems from upstream downstream are associated with nutrient loading (Nitrogen and Phosphorus) and organic compounds and lead to eutrophication due to release from agricultural, industrial and urban waste. These processes a well as silt loading result into deterioration in habitat quality, and affect and food chains.

Removal of the catchment vegetation including riparian wetland buffers, increases silt and nutrient loads into the rivers whose habitats become simplified. Climatic variability especially prolonged droughts has had negative impacts as well. Habitat degradation and loss lead to negative impacts on aquatic biodiversity. In polluted rivers and streams, aquatic organisms that are sensitive to oxygen stress and fluctuating temperatures e.g. Ephemeroptera, Trichoptera and Plecoptera tend to be replaced by organisms that live in mud with low oxygen content such as the Chironimidae and annelids.

Floodplains provide breeding and nursery habitats for migratory species such as *of Labeo victorianus, Barbus altianalis, Clarias gariepinus*. Fragmentation, channelisation and drainage have been practiced in the region and aquatic habitats have been lost. However, the decline to almost total disappearance of those fish species has been attributed to overfishing of the ripe-running fishes before they have bred the capture of young fishes before they have returned to the main lake and the building of dykes.

3.3.3. Trends in the riverine ecosystems

Human activity such as agriculture, fishing, urban development, water use has altered river ecosystems and influenced the types of goods and benefits derived from them. During the last century, the socio-economically most important goods from the rivers and streams, apart from water, were the migratory fishes (*L. victorianus*, *B. altianalis*, *C. gariepinus*, *S. afro-fischeri*, and *S. mystus*). The seasonal flooding of rivers was noted from the earliest times to be associated with large catches of these species. Up to the 1970s, about 20,000 mt of fish could be landed from the Kenya rivers with significant quantities also observed from the Kagera and Mara but these are no more.

The early fishing methods and techniques were primarily traditional (e.g. *Kek, Oluchiwira*, and *basket*) designed specifically for certain fishes at different times during the flood phase. The methods were replaced by mostly small (2.5” to 3”) mesh gill nets by the end of the 1970s. The operation of these nets as active gears at river mouths while ensuring good catches during the flood phase also led to a rapid decline in the riverine fisheries. The breeding biology of the fishes was applied to target ripe-running ready to breed fishes in large numbers. By the 1980s, total estimates of riverine catches had fallen to less than 500 mt.

The physico-chemical conditions in the Lake Victoria Basin have been changing but appear to have escalated from the mid-1970s. During this period, the water quality in the Nzoia River underwent modification with the construction of the Webuye Paper factory has deteriorated. Although there had been no baseline studies on water quality, management of the effluents was known to lack sufficient mitigation measures. Further down stream of the same river, embarkments/dykes were constructed to protect river side residents along the flood plain from flood waters. These developments arose out of the need to improve income and safeguard an increasing vulnerable population. Similar developments are associated with changes in the ecosystems of Rivers Yala and Sondu Miriu as well as the Kagera basin when dams for hydro-power generation, irrigation activities and urbanization have impacted natural ecosystem services in exchange for utilization of ecosystem goods.

Table 3.3.1. Comparative Mean flows from catchments around the lake for the main Rivers for the period 2001-04 and the long term mean of 1950 – 2000.

Country	Drainage Basin	LVEMP Study (1950-2000)		LVEMP (2001-2004)		Long term 1950-2004	
		Flow in Cumecs	*%*	*Flow in Cumecs*	*%*	*Flow in Cumecs*	*%*
Kenya	Sio	11.4	1.4	9.8	1.4	11.3	1.4
	Nzoia	116.7	14.5	107.4	15.7	116.1	14.6
	Yala	37.7	4.7	47.9	7.0	38.4	4.8
	Nyando	18.5	2.3	41.9	6.1	20.3	2.6
	North Awach	3.8	0.5	3.3	0.5	3.7	0.5
	South Awach	5.9	0.7	5.5	0.8	5.9	0.7
	Sondu	42.2	5.2	43.9	6.4	42.4	5.3
	Gucha-Migori	58.0	7.2	39.9	5.8	56.6	7.1
Kenya and Tanzania	Mara	37.5	4.7	23.1	3.4	36.5	4.6
Tanzania	Grumeti	11.5	1.4	4.6	0.7	11.0	1.4
	Mbalageti	4.3	0.5	3.5	0.5	4.2	0.5
	E. Shore Streams	18.6	2.3	11.3	1.6	18.1	2.3
	Simiyu	39.0	4.8	12.2	1.8	37.0	4.6
	Magogo-Maome	8.4	1.0	1.6	0.2	7.8	1.0
	Nyashishi	1.6	0.2	0.3	0.0	1.5	0.2
	Issanga	31.0	3.9	4.3	0.6	29.0	3.6
	S. Shore Streams	25.7	3.2	3.5	0.5	24.1	3.0
	Biharamulo	17.8	2.2	18.3	2.7	17.9	2.2
	W. Shore Streams	20.7	2.6	18.9	2.7	20.6	2.6
Burundi, Rwanda, Tanzania & Uganda	Kagera	261.1	32.4	252.5	36.8	260.5	32.7
Uganda	Bukora	3.1	0.4	2.0	0.3	3.0	0.4
	Katonga	5.1	0.6	2.1	0.3	4.9	0.6
	N. Shore Streams	25.6	3.2	28.2	4.1	25.8	3.2
	Total	805.3	100	686.2	100	796.6	100

3.3.4. Status of the riverine ecosystems

The introduced exotic species e.g. Nile perch and tilapias are common features in the LVB riverine ecosystems. Since the late 1980s, water hyacinth (*Eichornia crassipes*) invaded Lake Victoria. The entire Mukungwa/Nyaburongo/Kagera river system to Lake Victoria is infected with water hyacinth for a length over 500 km. These biotic components are associated with current biotic diversity in the entire LVB. The weed has spread to virtually all water bodies in the basin. In the main lake, water hyacinth was largely contained through a combination of biological and mechanical efforts in addition to environmental factors associated with *el-nino* rains. However, in rivers, water hyacinth persists.

Climatic variability in the LVB especially increased spells of drought in recent years has had negative effects on riverine ecosystem. In the 1960s, abnormally heavy rains in the basin were considered to have had beneficial effects on the breeding of riverine fishes. However, the cumulative effects of climatic variability and human activity have led to riverine habitat reduction and degradation. For example, drainage of tributary streams combined with removal of buffering vegetation especially swamps have resulted into drying up of entire streams that originally were habitats of fishes and other aquatic biota.

3.3.5. Gaps in information and data on riverine ecosystems

Information related to rivers as ecosystems including the source, elevation, tributary streams, vegetation cover and land use is lacking.

There are virtually no records characteristics and parameter on rivers such as length, discharge, the various water courses, nature of the river banks, and flooding regimes. Characterization of river beds has not been made.

From an ecological perspective, riparian vegetation and land use patterns have not fully been characterized. The types of vegetation along the banks indicate the influence of external inputs (e.g. organic matter in form of leaves, debris, etc) to the river while the absence of vegetation (e.g. due to land use) could indicate the source of turbidity of the river water.

Information is yet to be collected on the use and extent of river water whether or not this is for domestic, industrial or other use such as wastewater disposal from industry or settlements.

The human factors impacting the ecology of riverine ecosystems have not been classified.

For riverine ecosystems in the LVB information is mostly scattered in different institutions with different mandates. Information on hydrology of rivers is often nested in agencies responsible for water, while land use (agriculture) has most information on land productivity with information on land productivity with fisheries institutions having information on fishery aspects. Studies on aquatic biodiversity or riverine ecosystems in the LVB are dominated by riverine fisheries especially the use of indigenous fishing methods to trap fish during breeding seasons. Relevant information includes inventories of selected river fishes and to a lesser extent, on the ecology of the fishes and pollution threats. A database that improves the potential for improved management and conservation of aquatic biodiversity in the LVB can be designed according to the following formats in Tables 1 and 2 annexed below.

3.3.6. Recommendations to reduce the threats and fill gaps in information and data

Riverine ecosystems in the LVB significantly contribute to the water budget of the lake and to aquatic biodiversity in the basin. Human activity (agriculture, fishing, urban development, water use) and climatic variability pose major threats to the types of ecosystem goods and services derived from riverine ecosystems in the LVB. The socio-economically important riverine fisheries based on the migratory fishes have declined as have patterns of the seasonal flooding of the rivers which carry large quantities of silt to the lake.

There are deficiencies that have to be addressed in the knowledge base on rivers and streams of the LVB. However, there are in the basin countries appropriate policies and laws which need to be implemented to sustainably manage the riverine ecosystems. These include water use regulations, fisheries as well as environmental policies and laws. In addition, the LVB countries are either signatories to or are aware of international instruments such as CBD, CITES and the Ramsar Convention on Wetlands. The Mandate of the Lake Victoria Basin Commission should be more effectively used to increase governments' attention to the known obligations. In the short term, four major types of strategic interventions are recommended to protect biological diversity in the basin river ecosystems:

i) Developing strategically coordinated, locally-based projects that collectively address the most significant systems and stresses including water balance;
ii) Improving the basic and applied science necessary for biodiversity conservation;
iii) Increasing awareness of the basin's biological diversity and of methods to conserve that diversity;
iv) Increasing support to regional institutions, both governmental and private, for the protection of biological diversity.
v) Establish monitoring programs to determine the impact, real or potential, of human activities around the rivers.

3.3.7. Facts about the LVB riverine ecosystems

i) There are numerous rivers and streams in the LVB, most of them flowing into Lake Victoria. The most important in terms of size and length are Kagera, Nzoia, Mara, Sondu-Miriu, Nyando, Kujja, Katonga, and Sio. These contribute about 18% of the water volume of Lake Victoria at any one time. There is only one outflow (the River Nile) which contributes about 24% of the water leaving Lake Victoria at any one time.
ii) The river basins are prime areas of human settlement as they are immediate sources of water, food fish, and hydro-power generation.
iii) The river fisheries were till the 1960s important due to migratory fishes such as *L. victorianus*, *C. gariepinus*, and *B. altianalis*. These species of fish occur in lake ecosystems of the basin but utilize riverine environments for breeding.
iv) Major threats to rivers in the LVB are primarily human-induced in the land cover through removal of natural vegetation, siltation, pollution, over-exploitation of the resources such as the fisheries and climatic variability.
v) In comparison to other ecosystems in the basin, river ecosystems are the least studied, and where there have been studied, there have been intermittent with no systematic trends.

3.4. WETLAND ECOSYSTEMS IN LAKE VICTORIA BASIN

3.4.1. Introduction

Wetlands are areas of land that are permanently or seasonally flooded by water. Most wetlands are natural but some are man-made. They are usually transitional zones (ecotonal) between land and open water systems. Wetlands include areas of seasonally flooded grassland, swamp forest, permanently flooded papyrus, grass swamp and upland bog. Wetlands are internationally defined as: *"areas of marsh, fen, peat land or water, whether natural or artificial permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres".* According to this definition, all the shallow areas of Lake Victoria, its rivers and satellite lakes in the LVB are wetlands.

3.4.2. Composition of wetlands in the LVB

Lake Victoria has about 13,114 wetlands occupying about 535, 453 hectares. The greatest concentrations of wetlands are in the lowland plains. The wetlands of the Lake Victoria basin support a wide range of economic activities. In Kenya for example, the wetlands sustain a significant proportion of the population of Nyanza and Western Provinces.

Wetlands are extensively distributed, particularly in the LVB. In Uganda, wetlands cover almost 30,000 km^2, i.e. ca. 12.5% of the total land area of the country and of this 9.5% are permanent wetlands while 3% are seasonal. Tanzania is very rich in wetland resources which include the Great Lake systems and major river networks.

The Kenya part of LVB region is approximately 47,700 km^2 including wetlands and catchment areas of the six major rivers that replenish the lake and its satellite water bodies i.e. Sio, Nzoia, Yala, Sondu, Nyando and Kuja.

3.4.3. Values of wetlands

Wetlands were previously regarded as wastelands and were often drained or used for disposal of waste. Their value began to be appreciated after the realization that development depends on and therefore needs a healthy environment. They serve as sources of materials for crafts, medicinal plants, soil for bricks and act as water reservoirs. LVB Wetland have potential for agricultural production especially in dry seasons for growth of crops out of season, aquaculture and grazing of animals. Wetlands provide suitable habitats and refuge for many animals including birds and fish and hence important for biodiversity conservation. Marginal wetland ecotones serve as breeding, nursery and feeding grounds for fish and other aquatic organisms. Wetlands buffer inputs from the catchment into lakes and rivers and their presence along rivers helps control flooding. They serve as large sinks for sediments, silt, nutrients, pollutants and toxins and are used for sewage treatment. Wetlands assist in maintaining water regimes, moderating climate and provide physical stability to the shores of lake. Wetlands are thus very productive ecosystems with high diversity of plants and animals.

3.4.4. Threats to LVB wetland ecosystems

There is heavy pressure on the LVB wetlands and their resources as land gets increasingly scarce for cultivation, dairy farming and other economic activities. This has led to shrinkage of the wetland estate in the whole region. The size of wetlands continues to decline in coverage and quality owing to a whole array of human activities. Despite the fact they were the first major ecosystem to be protected by an international treaty. In Uganda, NEMA estimated a loss of up to 80% and 15% of the original wetland cover in Jinja and Mukono Districts of Uganda. There has been a dramatic reduction in natural wetland cover since European settlement and 37% of Lake Victoria's wetland area has been lost, primarily as a result of drainage.

The dramatic drop in water level has dried the papyrus wetlands fringing the lake, resulting in collapse in tilapia fisheries recruitment. Loss of the key tilapia fish used by the local population living along the lake shores threatens the food security of people depending on the lake. Additional impacts include increased eutrophication and algal blooms. Invasion by the alien water hyacinth and accelerated climate change as the dried papyrus and its peat are burned to claim land for agriculture also pose a threat. Invasive species have had significant impact of the biodiversity of wetlands. In Nyanza Province, the acreage brought under cash and food crops and livestock production especially in the river flood plains has been increasing steadily in the region over the years. Some of this land was derived from wetlands.

Direct anthropogenic activities such as irrational use of wetlands for agriculture, pollution and conversion of wetlands into settlement areas are responsible for wetland degradation and loss. Problems of sedimentation as a result of agricultural activities, hydrological changes of wetlands due to road construction and excessive extraction of water are indirect results of human actions. Drought is also becoming a common natural cause for the change or loss of wetlands in the lake basin. Absence of a wetlands policy in some of the countries in the region, conflicting sectoral policies on issues related to wetlands, deficient planning concepts, limited information and awareness on the importance of wetlands and absence of an institution to deal specifically with wetland management in some of the countries contribute to degradation and loss of wetlands. Formulation of the National Wetlands Policy and launching of awareness campaigns on wise use of wetlands and carrying out of research on the proper utilisation of wetlands, monitoring of wetland uses and provision of sustainable exploitation of wetland resources extension services where these are lacking or weak would be commendable steps towards alleviation of the degradation of wetlands.

3.4.5. Principal drivers of change in wetland coverage

A number of factors underlie the continued shrinkage in coverage of wetlands in East Africa. These include poverty, lack of enabling policies or their enforcement in some of the countries in the region and rapid population growth.

Rapid human population growth has increased scarcity of good agricultural land and over-extraction of wetland resources. In the rural areas, small but continuous nibbling at the edges has reduced wetlands areas. In eastern Uganda, for example, almost all the seasonal wetlands fit for rice cultivation have been converted to that use, and in some parts of the southwest, large areas of wetlands have been converted to dairy farms or to cultivation.

Poverty arising out of limited livelihood options and lack of employment opportunities has promoted encroachment and over-exploitation of wetland resources.

Other factors which have promoted loss of wetland coverage include: Lack of a policy framework in some instances or policies being sectoral and uncoordinated; Land tenure systems of ownership which may not guarantee ownership or render wetlands a common property; Limited knowledge on the value and complex ecological function of wetlands; Poor and sometimes inappropriate technology used in resource use; Climate change leading to drastic changes in water regimes; Undefined wetland boundaries; Ineffective political support for development; Selfishness, greed and temptations to exploi potential resources; Urbanization and industrial development where wetlands are the last free or cheap areas for infrastructure development – in this case many sections of wetlands have been converted to industrial use, roads and some have gradually been taken over by semi-slum residential housing.

3.4.6. Efforts to manage wetlands in the LVB

The Partner States of the EAC are signatories to the Ramsar Convention and have made progress toward development of wetland policies since the 1990. Uganda has 11 Ramsar sites; Kenya's five, while Tanzania, Burundi and Rwanda have one each. In some of these countries, enforcement and actions are not yet achieved and some are yet to identify and designate some wetlands as Ramsar Sites in the LVB. There have also been isolated regional efforts to address wetland conservation challenges. These include those supported under SIDA, RELMA, NORAD, World Bank and EU

In Uganda, a Ministry of Environment and Natural Resource MWENR) identified wetland degradation as one of the key environmental issues. The National Wetlands Programme (NWP) was established in 1989 to develop a wetlands policy and methodologies to sustain the biophysical and socio-economic values of wetlands for present and future generations. On February 1st 2001, a Wetland Sector Strategic Plan - WSSSP - (2001-2010) was launched. A Wetlands Management Department has been established and makes efforts to enhance awareness at the national, districts and local level, inventory of wetlands and research on the values and functions of wetlands assisting communities in the development of community based Wetlands Management Plans. This has been piloted in some districts in the LVB. So far, 23 management Plans have been developed in the country and implementation of 10 of them is on going including the Kyojja and Nabugabo wetlands in the LVB. Government has also started the gazetting wetlands of critical importance for protection starting with Nakivubo wetland in Kampala.

Although Tanzania is endowed with abundant wetland resources, there has been no systematic national programme for monitoring, development and management of the wetland resources. Tanzanian accessioned to the Ramsar Convention on Wetlands in 1999 and approved the Malagarasi-Muyovozi wetlands as the first Ramsar site. In 2003, the Government of Tanzania established the National Wetland Steering Committee (NAWESCO), represented by 8 ministries to provide high-level coordination on policy and management issues related to wetlands. A five year Sustainable Wetlands Management Component began in 2004 and forms part of the Danish Environment Support Programme. The Component is directly supporting environmentally and socially sustainable management of land and water-based resources in selected wetland areas. National level functions needed for facilitating better management of wetlands are supported based on a multi-sectoral approach. It is assisting Tanzania's implementation of the Ramsar Convention on wetlands and promotes the further development of a national wetlands programme. It will also contribute towards Tanzania's Poverty Reduction Strategy by developing sustainable wetlands management at community, district, region, catchments, river basin, and national levels.

The management of wetlands in Kenya is currently under various institutions, whose mandates and activities are not only sectoral but also uncoordinated and sometimes overlapping. Kenya Wildlife Service (KWS), being the national focal point for the Bonn Convention on Migratory Species and the Ramsar Convention on Wetlands, has the mandate of conserving Kenya's natural resources including wetlands within the gazetted protected areas, which are the national parks and game reserves. This management preference leaves out many other important wetlands unprotected and under threat of degradation. Other institutions that have been involved in the wetlands management include National Museums of Kenya, the Ministry of Environment and Natural Resources, the Ministry of Planning and National Development, the Ministry of Research, Technical Training and Technology, Universities, Local Authorities, Regional Development Authorities, the National Irrigation Board and NGOs. Realizing the sectoral nature of the institutions mentioned above and the ever-increasing threat to wetlands, the Government of Kenya established in 1994 within the Inter-ministerial Committee for Environment (IMCE) a National Wetlands Standing Committee (NWSC). The committee consulted government and academic institutions, NGOs and community based institutions to build the necessary consensus on a clear national working definition of wetlands, and on elements to be included in the policy formulation. Consequently, the Committee has come up with the wetlands definition and has also drawn a framework within which the national wetlands policy will be formulated.

The above scenario shows that there is no harmonized policy for management of wetlands among the EAC Partner States. Since most of the wetland of the EAC are in the LVB there is need for the Partner States to harmonise the policy, legal and institutional frameworks for management of wetlands.

3.4.7. Gaps in information and data on wetlands ecosystems

Some of the gaps in information and data on wetlands include the following:

i) Not all wetlands have been inventoried and there is little or no information on biodiversity, socio-economic and other issues in some of them;
ii) Information on quantities of resources harvested, modes of extraction and trends of resource use is scanty;
iii) Information on resource valuation and the contribution of wetlands to national economies is very limited;
iv) The conservation status of most elements of biodiversity especially species, but also ecosystems, is lacking in most wetlands;
v) Water quality studies are pretty scanty and the capacity of wetlands to accommodate influx of materials including pollutants and toxins not well known;
vi) Patterns of water level change not well known. Little data is available on hydrological and hydrochemical aspects;
vii) Information on traditional knowledge and indigenous methods of wetland resource management is scanty;

viii) Levels of community awareness about the contribution of wetlands to their welfare and support to life systems (ecological services and non-tangible benefits) not explicitly provided in many studies;
ix) Information on strengths and weakness, opportunities and challenges with respect to wetland users, managers, planners and scientists scanty;
x) Extent of collaboration in the region in wetland management and conservation not well highlighted; and
xi) Information on policy instruments not prominently available.

3.4.8. Conclusions and recommendations to reduce the threats and fill the gaps in wetlands

There is some information about wetlands in the region. Institutions and individual researchers have carried out research on various aspects of wetlands including, but not limited to, species inventories, limnology and water quality, biodiversity conservation, among others. This has however not been effectively used in planning conservation of wetlands nor in guiding policy in some cases. A lot more areas are still data-deficient and need to be further strengthened to generate information for proper wetland planning and management. Top among these research needs is the issue of monitoring of several aspects of wetlands. It is evident that there is very little information available about trends and patterns of many wetland issues such as resource availability and distribution. There is need for coordination of research activities at all stages including identification of priority areas, methods, analysis of results and report discussion and also establishment of common data standards. This will improve information sharing in the region and data interoperability. Specific areas of intervention include the following:

(i) All main wetlands need to be inventoried and documented to generate adequate scientific and other information through research and inventory. This should include extent, location and distribution.
(ii) Wetlands with critical conservation issues such as highly threatened taxa and habitats should be accorded protection status to strengthen and effectively utilize the wetland policy where it is in place.
(iii) Sustained monitoring programmes should be a matter of policy so that ecosystem health trends and patterns on several important aspects of wetland management and conservation may be discernible.
(iv) Studies on indicator taxa need to be strengthened to assist monitoring of ecosystem health.
(v) Impact of climate change on water level of the lake, health and coverage of the wetlands be studied and monitored.
(vi) Studies on habitats and water quality in the wetlands should be strengthened as a simple indicator of environmental change.
(vii) There is need for recognition and integration of traditional management practices of the user communities in wetland management programmes through incorporation into the natural resource management policies.
(viii) Rational assessment of levels of awareness is needed and where need be, sensitization programmes be carried out to enhance awareness on threats and impact of human activity on wetlands.
(ix) Capacity needs to should be built at community level for proper and wise use of the wetland resources in their areas of locale through training and development of easy to use manuals.

(x) Gender differentials in resource use need to be considered and integrated in management planning and training.
(xi) The influence of land tenure systems on the level of wetland appreciation and protection by the communities, resource extraction and management need to be assessed.
(xii) Valuation of resources in the wetlands should be carried out to reflect the contribution of wetlands to the economy of the countries in the region.
(xiii) Regional and international collaboration, especially on migratory species and trans-boundary wetlands such as the Kagera and Sio-Siteko systems.
(xiv) Developing enabling policies, institutional, legal and administrative frameworks where these are lacking and enforcing them for sustainable management of wetland resources.
(xv) Countries in the region that do not have a central body responsible for management of wetlands need to create them so they may coordinate and implement wetland conservation programmes.

3.4.9. Key facts on wetlands

Some of the key facts on wetland resources are as follows:

i) Wetlands in the Lake Victoria Basin are crucial for community livelihoods and biodiversity conservation
ii) The Lake Victoria Basin wetlands are the most extensive in East Africa
iii) The extent of coverage has continued to decline in the region basically due to human activity
iv) Conversion rates of up to 80% have been registered in some instances
v) Destruction of marginal wetlands has exposed Lake Victoria to siltation and eutrophication.
vi) Monitoring programmes are strongly lacking in the region
vii) Most wetlands are outside protected areas
viii) There is lack of adequate management frameworks (policies)
ix) Utilization of wetland resources is unsustainable in many instances
x) Integrated planning of wetlands through a participatory and multi-disciplinary approach is an important strategy.

3.5. THE DIVERSITY OF MACROPHYTES

3.5.1. Introduction

Aquatic macrophytes are a component of wetlands and constitute the most visible part of the wetland biotic communities. Species diversity and richness are some of the good indications of ecosystem health and level of development in the succession cycle. Species richness is influenced by a number of factors including productivity, area, habitat heterogeneity, regional and evolutionary history, synergism between climate and evolutionary history. Climatic factors, especially rainfall and temperature, contribute to the richness of an area. The shallow bays provide favourable conditions for emergent and submerged macrophytes. These factors tend to exert their influence in concert rather than in isolation.

3.5.2. Composition of aquatic macrophytes

Aquatic macrophytes are either anchored, open water submerged, or open floating. Open water sub-merged macrophytes are completely covered under water. They have no anchorage to the bottom of the water body. Common among these in the region are *Ceratophyllum*, *Lagarosiphon* and *Najas* in the open water zone. Floating macrophytes are those that float on the water surface and their roots are not anchored to the bottom of the water body. The common ones in this group include: *Pistia*, *Eichhornia*, *Lemna*, *Azolla*, *Spirodela*, *Wolffia*, *Nymphaea*, and *Salvinia*. Anchored macrophytes are those with roots that penetrate the bottom substratum of the water body. Most of these grow at the edge of water bodies where the water is shallow. They may be emergent as in *Cyperus*, *Nymphoides*, *Leersia*, *Persicaria*, *Ipomoea aquatica*, *Ludwigia*, *Phragmites*, *Vossia* or sub-merged as in *Caldesia*, *Burnatia*, *Potamogeton*, *Aponogeton*, *Ottelia, Utricularia.* Another scheme for categorization of the macrophytes is based on natural classification of groups of plants thus: Grasses (Poaceae) such as *Vossia* and *Phragmites*; sedges (Cyperaceae) such as *Cyperus* and *Cladium*; Water Lilies (Nymphaeaceae); and Bulsruhes (Typhaceae).

The commonest macrophytes include bulrushes (*Typha spp*), papyrus, *Miscanthus* sp., *Phragmites* sp., *Echinochloa, Vossia*, *Limnophyton*, *Loudetia*, *Dissotis*, and *Leersia*. The open water systems support floating plants as well as submerged forms while edges of the water bodies support growth of anchored plants such as *Vossia cuspidata*. The diversity and biomass of the vegetation tend to be higher at the shallower edge of water bodies. Some plants that grow in wetlands are tolerant to flooding. These plants are adaptable to presence of water to varying degrees and some grow floating or submerged in the open water and are purely aquatic e.g. *Potamogeton* sp., *Ceratophyllum* sp., *Pistia stratiotes* and the invasive *Eichhornia crassipes.* Others only grow in seasonally flooded areas such as floodplains in grasslands e.g. *Chloris gayana*, *Drosera* sp. and *Eragrostis mildbraedii*. *Typha* indicates a high level of salinity. *Miscanthus* is indicative of low nutrient level and high acidity. Such environments are dry enough to support *Sphagnum* and other bryophytes.

In Sondu-Miriu wetlands in Kenya, 34 species of plants are known. These form varying communities of *Cyperus papyrus*, *Cladium mariscus* ssp. *jamaicense*, *Cyperus latifolius*. The Yala Swamp and Nyando Delta have *Echinochloa pyramidalis*, *Phragmites* sp., *Cyperus papyrus*, *Typha* sp. and *Vossia cuspidata* as the most dominant. Common floating species include water ferns (*Azolla*) and Duckweed (*Lemna*), Water Lettuce (*Pistia*), and now the alien water hyacinth (*Eichhornia crassipes*). In open water areas grow submerged plants including *Najas*, *Potamogeton*, *Aponogeton abyssinicus*, *Ceratophyllum*, *Caldesia*, *Nymphaea* and *Lagarosiphon*. These quickly respond to changes in the physical and chemical properties of the water. They are thus sensitive to pollution. In Uganda, the Nabugabo wetland system is particularly rich in sedges and all vascular plants with over 300 taxa recorded.

3.5.3. Invasive aquatic macrophytes

Invasive species including some aquatic macrophytes are usually alien even though sometimes native species may attain invasive status (i.e. weeds). After they are introduced, they spread naturally without direct assistance of man in natural and semi-natural habitats, producing significant change in composition, structure and ecosystem function. They often grow very prolifically, building up large populations and biomass rapidly. They pose a major threat to biodiversity and impair socio-economic integrity of water resources. By far the most striking and devastating invasion of the Lake Victoria ecosystem in the modern times is by the water hyacinth, *Eichhornia crassipes*. First observed in the 1960's on Lake Victoria, it remained at low levels until in the early 1990's when it proliferated. It rapidly spread to nearly all the bays and gulfs, changing the aquatic landscape features of the lake and the associated wetlands in all the three East African countries. Its aggressiveness significantly changed the species diversity and composition of the macrophytes in the basin. These changes also affected the faunal assemblage in the affected areas through impacts on the complex food web networks including fish, invertebrate fauna, as well as the physico-chemical conditions of the water, particularly the oxygen levels. Kenya's wetland and aquatic ecosystems were estimated to have water hyacinth coverage of 6,000 ha in 1999. The plant also occupied key microhabitats and spawning/nursery ground for fish thereby reducing fish productivity. The decomposing organic material owing to its high turnover rate settles and causes a high Biological Oxygen Demand (BOD) in the water, thus suffocating aquatic life.

Several other invasive macrophytes are common in the Lake Victoria basin. *Mimosa pigra* is a shrub noticeable in the wetlands around the main lake. It is common in disturbed areas and more common at the wetland edges where there is frequent grazing and other disturbances. If left unabated, it forms thickets reducing the abundance of other plants. *Vossia cuspidata* is a grass which can also spread fast on lake or dam fringes. It overshadows other aquatic plants thus reducing biodiversity. *Pistia stratiotes* (Water Lettuce) is another macrophyte invading wetlands and water systems in the region. It is a floating plant which can form large mats precluding oxygenation of the water and thus causing deleterious effects on the biodiversity of the invaded area just like the water hyacinth. *Azolla* sp. is usually found in irrigated areas with stagnant or slow-moving water.

3.5.4. Values of aquatic macrophytes

Aquatic macrophytes as autotrophs (self feeding from light) are at the base of the food chains of other organisms. The macrophytes generate oxygen required for the respiratory processes of all biota such as fish, amphibians, reptiles, birds and mammals. They provide cover to prey species of animals from predators and also food for the animals such as *Sitatunga*. They take up large amounts of nutrient carried by running water from terrestrial systems and thus regulate nutrient build-up which would cause significant changes in the chemical properties of the water and biotic composition. Aquatic macrophytes are used as food, medicine, craft materials, building materials and fuel wood.

3.5.5. Threats to aquatic macrophytes

The very threats to aquatic macrophytes that affect the plant or their habitats include over-exploitation including grazing; burning, pollution and invasive species: Some of the macrophytes in wetlands (e.g. *Cyperus* spp) and aquatic systems are heavily extracted for fuel, building and commercial activities impairing their regenerative potential. Wild fires are often set in habitats of macrophytes in the region, damaging and destroying vast areas. This is a common illegal practice in papyrus swamps by hunters, especially for Sitatunga. Over-grazing and cultivation in the floodplains and at the edges of wetlands or over cultivation by pastoralists and farmers destroy the plants growing in these areas. The mineral and pollutant uptake by macrophytes in aquatic systems and wetlands is high as most of them have a high growth and turnover rate. They are thus susceptible to pollutants from domestic sewage, industrial effluent, and agro-chemicals. Where the invasive plants grow, they tend to suppress other plants especially when the invaders are exotic as they find few, if any, natural enemies in their new environments. This leads to reduction of biodiversity through the displacement of the indigenous flora and disruption of the faunal food web network.

3.5.6. Key threatened aquatic macrophyte taxa

Even though some of the dominant macrophytes such as *Cyperus* spp (*C.* papyrus) have a high regeneration capacity, their over harvesting and frequent burning could further reduce their cover. By far the most challenging threat is a combination of drainage and degradation of suitable habitat for the macrophytes. The submerged species become more prone to local exclusion by the more aggressive weedy species such as *Eichhornia crassipes*. The large water hyacinth limits light penetration to the submerged and floating plants, hindering their growth. Therefore submerged species such as *Ceratophyllum*, *Lagarosiphon, Ottelia* and *Najas* are also threatened.

3.5.7. Trends in macrophyte cover

There is little data and information on trends of macrophyte abundance, distribution and other aspects in the region. There has been increased sedimentation on the lake shore and siltation on the floodplain although this is not well documented. This has resulted in significant reduction in abundance of *Cyperus papyrus* while grasses such as *Phragmites* and *Miscanthus* have increased. Consequently, *Vossia cuspidata* and *Phragmites mauritianus* now dominate some wetlands such as the Nyando and Sondu-Miriu floodplains.

3.5.8. Principal drivers of the changes

The underlying drivers of change in species composition and abundance of macrophytes include: rapid human population increase which results into heavier pressure on the plant resources, poverty and limited livelihood options. Land ownership systems generally do not accord responsibility and care for macrophytes sustainability. This may be due to inadequate awareness and knowledge about option values for plants such as development of pharmaceutical products, industrialization and urbanization.

3.5.9. Management and conservation actions of aquatic macrophytes

No specific species action plans are in place for macrophytes in the basin. However, some species especially the management strategies are adapted from the ecosystem approaches to management and conservation. However, certain situations such as invasive plants have warranted specific management approaches. Thus, on the international scene, the Global Invasive Species Programme (GISP) and IUCN are promoting the understanding of wetland invasive plants both from the perspective of human welfare and biodiversity conservation. The East African region has a programme for management of invasive species such as *Mimosa pigra*. The Kenya Agricultural Research Institute also has efforts to control invasive aquatic plants including biological control means. Cultural and policy approaches have included quarantine controls e.g. on the water hyacinth to reduce its spread. The Kenya Plant Health Inspectorate Services (KEPHIS) has a responsibility of inspecting the imported and exported plant materials in Kenya. In 1999 ICIPE, through its Biodiversity and Conservation Programme, started efforts of gathering information on the status of invasive plants and management needs in the Eastern Africa region.

There have been major efforts to control the water hyacinth since its invasion of Lake Victoria and associated water bodies systems.

3.5.10. Gaps in information and data on aquatic macrophytes

Studies on macrophytes in wetlands and aquatic systems in the region have often been focused on particular aspects such as socio-economic elements. Not many studies have encompassed the whole realm of macrophyte diversity for biodiversity assessment. Gaps in information and data on aquatic macrophytes are summarised as follows:

i) There is no empirical data readily available on the trend in abundance of specific species of macrophytes in the region.
ii) Some macrophytes such as Vossia are good indicators of environmental conditions and variability but little information is available on this subject.
iii) The extent of coverage of invasive species, their impact on biodiversity and human economic activity as well as their potential uses are not well known.
iv) The impacts and effectiveness of control measures of invasive species have not been evaluated.
v) Community awareness on invasive species is low.

3.5.11. Recommendations to reduce the threats and fill gaps

Many of the aquatic macrophytes in the LVB have narrow habitat preferences, thus being rendered susceptible to decimation due to habitat loss or modification. They are heavily used for many purposes by communities. This use is not regulated in most cases and over-exploitation poses threats to the macrophytes and their services. Some invasive alien macrophytes have been introduced, threatening further the survival of biodiversity and ecosystem health as well as human welfare. The water hyacinth is by far the biggest challenge in the modern times. The biggest gap in information is about the trends of habitat coverage and population levels of macrophytes. This requires a well planned monitoring programme in the region with harmonized and standardized methods. Other specific interventions required include the following:

i) Comprehensive macrophyte inventories are required in order to document the wealth of macrophytes in the region.
ii) Assessment of the conservation status of the macrophytes needs to be done, at least at national and regional level.
iii) Results of the conservation assessments above would be used to formulate specific Species Action Plans as part of the management intervention measures to save those macrophytes flagged as threatened.
iv) The policies on natural resource management in the region should clearly emphasize the importance of monitoring of species composition, diversity, abundance and distribution of macrophytes. The observed patterns of change and trends could then form a basis for intervention.
v) Determine key species of macrophytes performing vital functions such as filters of pollutants and silt, and indicators of environmental change. These should be prioritized in management and conservation strategies for their continued survival and service.
vi) Explore the potential use of invasive macrophytes so that they could be controlled through extractive use.

3.5.12. Key facts about macrophytes

i) Sedges (Cyperaceae) are dominant macrophytes in wetlands.
ii) Some aquatic habitats with macrophytes typically have low Oxygen levels and high moisture content. The gigantic C. papyrus and other large macrophytes limit oxygenation of water beneath them.
iii) Many of the macrophytes growing in wetlands and aquatic environments usually have special adaptations for coping with low oxygen and high water levels.
iv) Many macrophytes are habitat specific, growing exclusively in wetland or aquatic habitats and no other kind of habitat.
v) Many macrophytes are food to fish.
vi) Macrophytes are heavily depended upon by communities in the region for a livelihood as sources of food, fuel wood, craft materials, medicine and building materials.
vii) Some native and alien macrophytes are invasive and pose a threat to biodiversity and ecosystem health as well as human welfare.
viii) The main threats to macrophytes are alteration of their habitat and over-exploitation.

3.6. ALGAL SPECIES DIVERSITY

3.6.1. Introduction

The first general floristic survey of the African lakes began at the turn of the nineteenth century, and initial phytoplankton samples from Lake Victoria were collected at Bukoba in 1892. In Lake Victoria, the earliest records of algal type and primary productivity stretch from the late 1950s and 1960s. These historic records provide a benchmark for algal trends that have been analysed up to the 1990s in some of the lakes, especially in Lake Victoria.

Pollution, conservation of biodiversity and the drastic loss of fish diversity in Lake Victoria have stimulated investigations of algal flora in the lake. Algal studies done in the early 1990s and their checklists indicate that approximately 500 intrageneric taxa with over 100 genera are described for the African Great Lakes. Due to their paleoecological significance, diatoms are better known.

3.6.2. The major components of algae

The number of species in different families of algae in Lake Victoria and its satellite SWBs is summarized in Table 3.5.1. The algal community in the LVB is dominated by Cyanobacteria (blue green algae,), followed by Chlorophyceae (green algae), Bacillariophyceae (diatoms), and Chrysophyceae (Brown). The Chrysophytes and Dinophytes (dinoflagelletes) are also represented in some water bodies. More than one of these groups may occur simultaneously in lakes and rivers but may not be represented in equal proportion and others can be absent.

Table 3.5.1. Range in number of phytoplankton species in each major algal group in Lake Victoria and its satellite small water bodies.

	Lake Victoria		**SWBs in Uganda**		**SWBs in Kenya**		**SWBs in Tanzania**	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Cyanophyta	20	31	9	28	1	5	2	20
Chlorophyta	21	26	4	23	0	5	4	23
Bacillariophyta	9	111	1	14	0	5	3	9
Dinophyta	0	7	0	0	0	1	0	1
Euglenophyta	2	5	0	5	0	1	0	2
Pyrophyta	0	1	0	2	0	0	0	0
Chrysophyta	0	2	0	1	0	0	0	1
Cryptophyta	0	1	0	2	0	0	0	1
Total species number	67	169	24	69	4	13	18	55

Chemical, physical and hydrological factors largely determine the algal communities and species composition. Variations in these factors can induce responses at cellular and community levels up to the ecosystem scale. Consequently, the ecological integrity of several of the East African lakes has been altered as a result of changes in their physical, chemical and biological properties. These changes have, in turn, had impacts on the quality and quantity of algae, especially in Lake Victoria. The modifications of the water chemistry and physical environment of Lake Victoria have been invoked to explain succession of algal species composition. The historic diatom community of *Aulacoseira* (*Melosira*) and *Cyclostepha-*

nos made up 70-99% of the diatom biomass during periods of stable thermal stratification (March-April) and deep complete mixing (July) in 1960s have been replaced by *Nitzschia* that now dominates the diatom community.

Cyanobacteria (blue-green algae) abundance was very low in the 1960s but they presently appear more frequently. Filamentous cyanobacteria such as *Cylindospermopsis* make up a large fraction of the algal community of the lake. Green algae now occur in very low abundance and several taxa; in particular desmids that were present in 1950s-1960s have declined or disappeared. The large chlorophytes such as *Pediastrum* are rare.

Phytoplankton biomass as chlorophyll a (Chl-a) or biovolume has increased 6-fold or more since the 1960s. The changes in phytoplankton biomass and species composition have been attributed to increases in phosphorus (P) and nitrogen (N) loading, changes in fish communities and climate change. The current global warming and overall climate change could be contributing factors in stimulating phytoplankton blooms and driving algal diversity towards domination by cyanobacteria. It is also probable that biotic changes particularly fish species introductions enhanced changes in algal species composition through the trophic cascade effects in Lake Victoria. Changes in algal species composition occurred concurrently with changes in fish community composition that included loss of a tremendous diversity of endemic detritivorous and phytoplanktivorous haplochromine fish species and two endemic tilapiine cichlids (*Oreochromis variabilis* and *O. esculentus*), and establishment of the introduced Nile Perch (*Lates niloticus*) and Nile Tilapia (*Oreochromis niloticus*).

3.6.3. Threats to phytoplankton communities

Over the past decades, there have been dramatic changes in overall biodiversity in some of the water bodies of the LVB. In Lake Victoria, rates of nutrient cycling have increased and blooms of noxious algae threaten the water quality for various uses. In addition, changes in the food web have resulted in more invertebrates (such as *Caridina*), which enhance nutrient cycling and biomass decomposition in the sediments. The increased algal growth coupled with changes in stratification and mixing have reduced oxygen concentrations so that up to 50% of the volume of the lake is not habitable by fish for most of the year.

The changes in the nutrient status and physical-chemical conditions have affected the diversity of algal species in the LVB and some of them are virtually extinct. In addition, increased water temperatures with accompanying thermocline stability does not favour diatom growth; increases in ambient water temperatures is partly attributed to increased particulate matter in the aquatic systems and apparent regional climate change. Diatoms prefer relatively low temperatures and need some turbulence to keep them in suspension. This, coupled with the reduction in Silica content has affected the diversity of diatoms to the extent that the diatoms *Synedra* and *Melosira* are virtually extinct in Lake Victoria. Low silica concentrations in Lake Victoria and low light availability have lead to the reduction in abundance of some diatoms such as *Stephanodiscus* and *Cyclotella*. The low nitrogen concentration has favoured proliferation of certain blue green algae such as *Microcystis* and other small coccoids. These algae have a biological advantage of fixing atmospheric nitrogen.

All green algae such as *Ankistrodemus, Pediastrum, and Cosmarium* are endangered due to limiting N concentrations which has been caused by excess P loading (Figure 3.5.2). They are also over-grazed by invertebrates and fish as they are the most preferred taxa due to their high nutritional value.

3.6.4. Increases in algal production and biomass in Lake Victoria

Blue-greens are the dominant algae in the LVB (Figure 3.5.3). The predominance of blue greens is a function of many interacting factors but is greatly influenced by light and nutrients. Nutrient loading exerts a strong selective force on algal community and in turn affect total algal biodiversity in an ecosystem. Low nitrogen (N) to phosphorus (P) supply ratios favours dominance of blue-green algae. This has been manifested in Lake Victoria where the rapid increase in the concentration of P has not been matched with that of N which has favoured those algae with the capacity to fix N. Nutrient loading regimes into aquatic systems due to human activities such as agricultural fertilizers and sewage input will therefore alter algal species composition.

Equatorial lakes, like those in the LVB exhibit considerable seasonality in algal species composition related to alteration of temperature, stratification and mixing. Algal species composition changes seasonally in response to variations in the light environment and nutrient availability (Figures 3.5.1 & 3.5.2). Over the past decades, changes in nutrient status in Lake Victoria and its basin have effected algal species composition. Data collected from Lake Victoria between 1960s and 1990 shows that there have been changes in changes in nutrient, thermal and oxygen regimes (Figure 3.5.4) as well algal and fish communities. The concentration of Silicon (Si) has decreased ten times (Figure 3.5.1) resulting in changes in the diatom composition from *Aulocosira (Melosira*) and *Stephanodiscus* in the 1960s to *Nitzchia* and blue-green algae since the 1990s. Changes in nutrient chemistry, particularly in P and Si concentrations have changed the nitrogen cycle resulting into increased biomass of nitrogen fixing blue-green algae. Increases in blue-green algal blooms are a threat to overall aquatic biodiversity and water quality through production of phytotoxin that degrades the water environment and affect other biotic communities.

Thermal stratification and mixing patterns as recorded in Lake Victoria (Figure 3.5.4) may also cause changes in algal biodiversity and general water quality. Lake Victoria is subjected to seasonal mixing which redistribute nutrients throughout the water column. Changes in wind, solar energy and temperatures have changed the mixing patterns and intensity with a contracted period of mixing between June and August. This may permit more extreme hypolimnetic oxygen deficits and establishment of nitrogen fixing blue green algae.

Studies have shown that nutrient enrichment especially of P comes from human activities such as bush burning; sewage disposal from domestic, municipal and industrial sources and poor land use practices in the catchment areas. Management of human activities in the catchment areas is therefore key to the management of algal diversity in the LVB. The other factors that enhance internal nutrient recycling especially the role of invertebrates (zooplankton and benthos) in enhancing nutrient recycling needs to be understood.

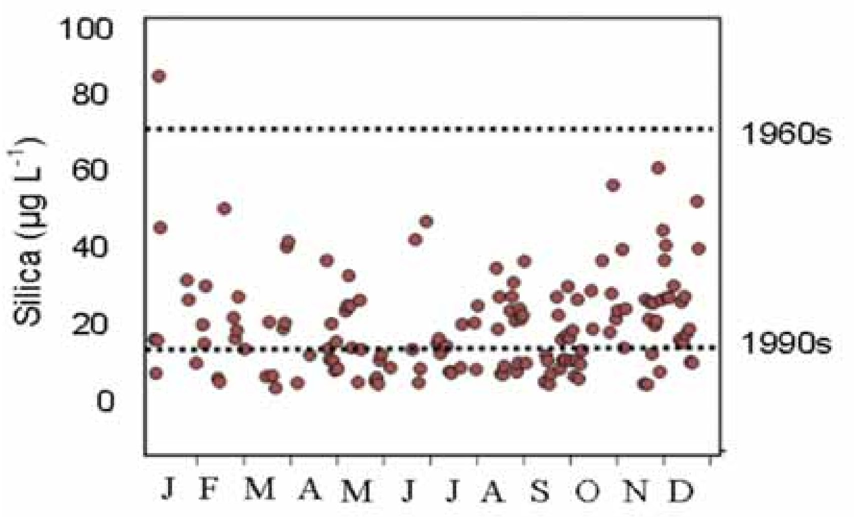

Figure 3.5.1: Comparison of Silicon concentrations in Lake Victoria in the 1960s and 1990s (the horizontal broken lines are the respective mean values).

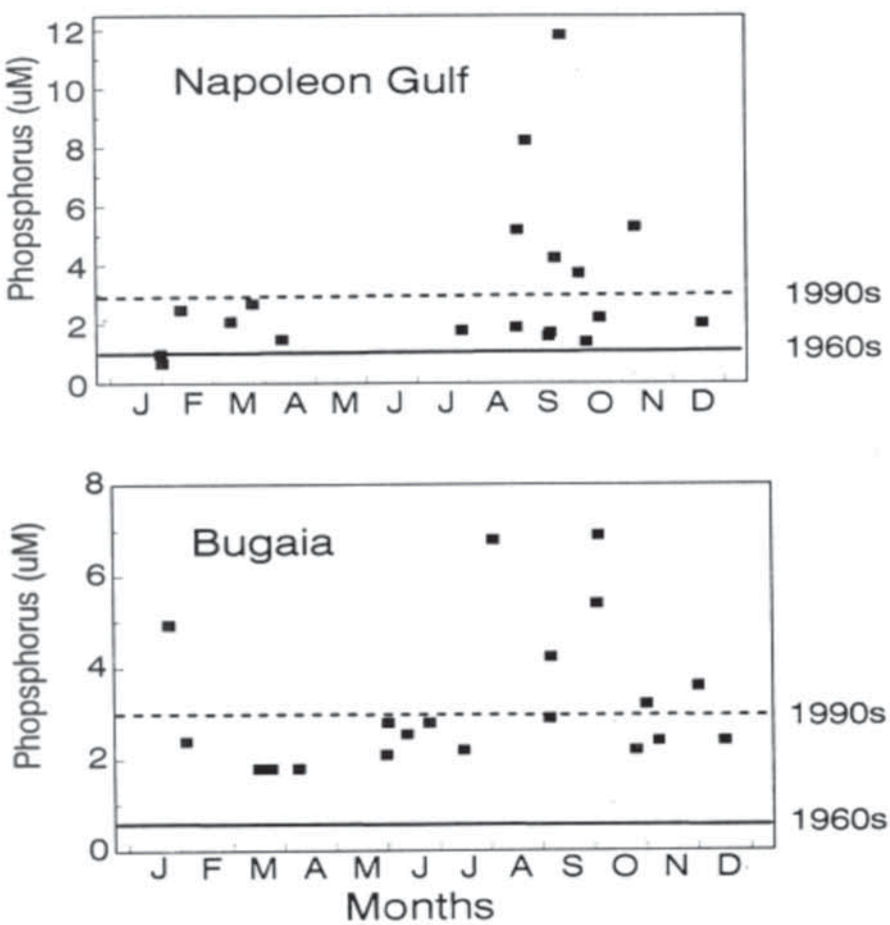

Figure 3.5.2: Comparison of P concentration during 1960 and 1990 at inshore and offshore stations of Lake Victoria

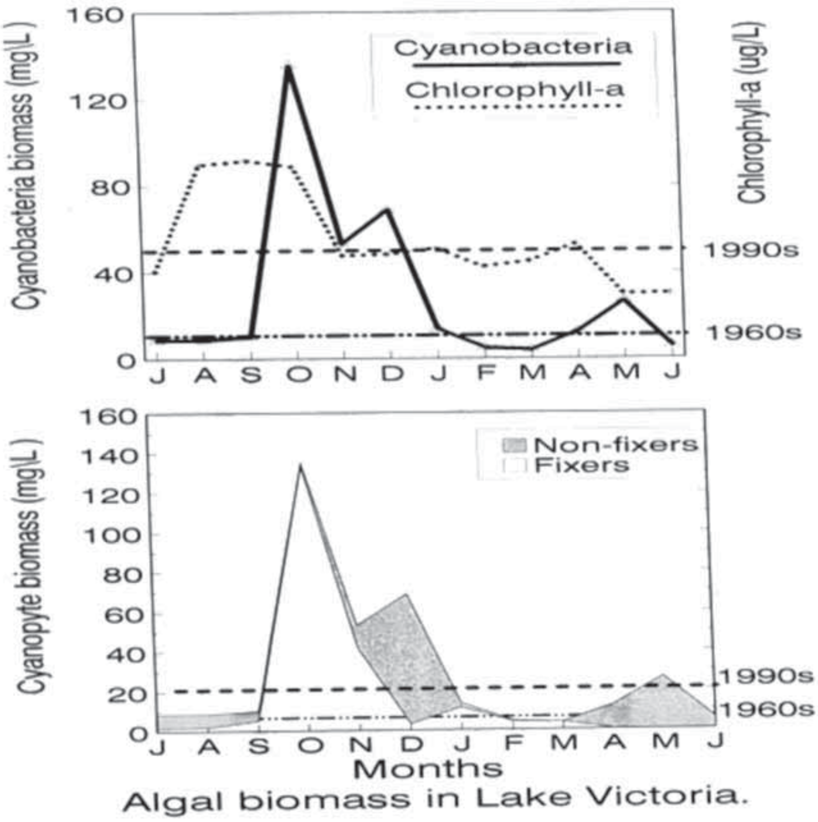

Figure 3.5.3: Comparison of algal biomass in Lake Victoria during the 1960s and 1990s

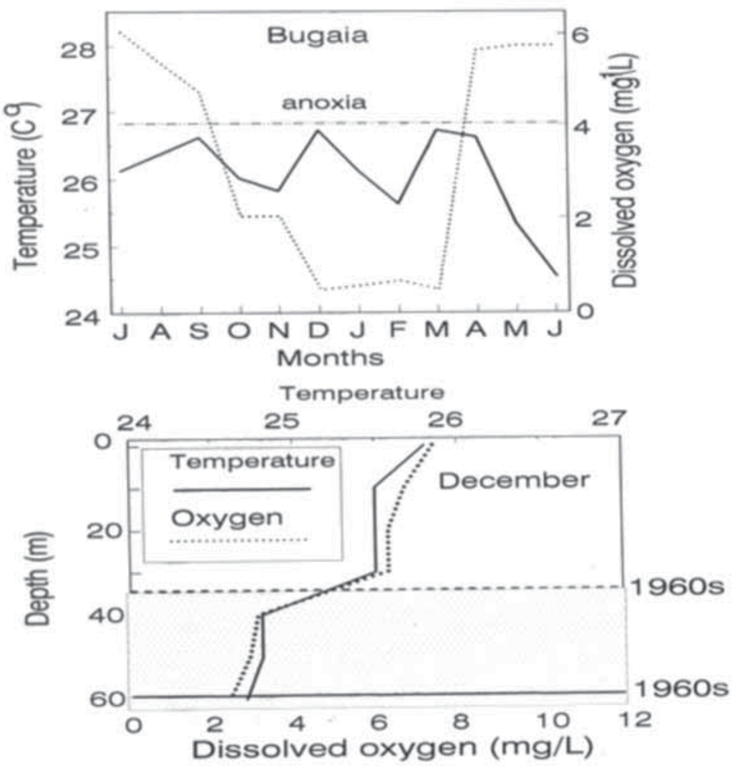

Figure 3.5.4. Thermal stratification and the spread of anoxia in Lake Victoria

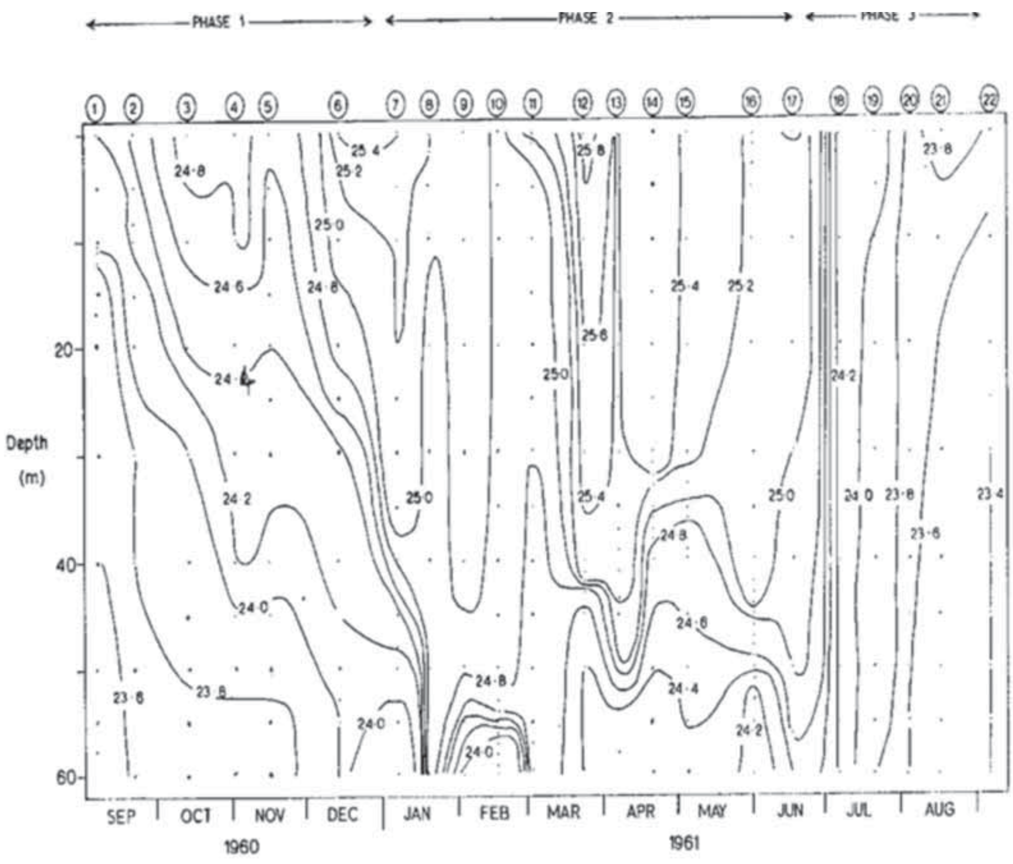

Figure. 3.5.5. Thermal stratification and mixing patterns of Lake Victoria

3.6.5. The drivers/indices of change in algal diversity

The composition and relative abundance of algae are determined by environmental factors especially nutrients and light conditions. The growth of algae depends on dissolved nutrients, trace elements, light and temperature. Algal diversity often changes with depth. The negatively buoyant algae such as diatoms settle down in the deeper parts of the lake where light is too low to maintain growth of other algae. In this way the hypolimnion serves as a micro-habitat with its characteristic algal diversity that is adapted to low light conditions. The positively buoyant blue-green algae stay in surface waters where temperatures are relatively higher. Deeper lakes with insufficient light in deeper waters hardly support benthic algae. Changes in light conditions will therefore influence algal composition and diversity.

In shallow aquatic ecosystems, water mixes frequently, and this prevents stratification. But even then, zonation and therefore diversity of habitats exists. Nutrient rich sediments with substantial amounts of light reaching the bottom support benthic algal communities.

In lakes, distinctive environments/habitats namely, the epilimnion, metalimnion and hypolimnion can be recognized. These habitats are separated by relatively abrupt discontinuities in identifiable characteristics especially of nutrients. These habitats vary on different scales either annually, seasonally, or daily. Gradients of underwater light penetration or hydrostatic pressure exist with depth across the habitat types and to the next habits and subsequently changes or affect algal biodiversity resulting in horizontal and vertical patchiness in algal species composition. In large lakes, such Victoria, horizontal, vertical and seasonal differences in the water environment result in succession in algal species composition.

3.6.6. Gaps in information and data on algae in the LVB

Understanding of processes inside and outside the aquatic systems, and their interactions, is required for any management of aquatic biodiversity especially of algae. There is inadequate information on the following:

i) changes in the food-web structure of the micro and macro organisms feeding on algae;
ii) status and trends in water quality of most lakes and rivers and how these affect algae;
iii) nutrient status and pollutant sources into lakes, and how these affect biodiversity including algae;
iv) physical environment of the lake i.e. the natural changes in wind, solar energy, mixing patterns or regimes and temperature are not adequately known;
v) Most of the data on algal species diversity is available only for Lake Victoria and there is need to collect information from other water bodies in the LVB.

3.6.7. Recommendations to reduce the threats and fill gaps on algae in the LVB

i) A shift to dominance by blue-green algae in Lake Victoria presents a problem that calls for scientific investigations and requires appropriate management to mitigate loss of algal diversity which inevitably affects other resources in the aquatic ecosystems.
ii) There is urgent need to carry out algal diversity surveys in lakes that have not been studied yet to determine if what is happening in the main lake and some satellite SWBs is a regional phenomenon.
iii) The remedial action for a deteriorating water quality is to control nutrient loading especially of phosphorus.
iv) Given the eutrophic condition of most of the lakes as indicated by water column characteristics of high concentrations of phosphorus (P) and nitrogen (N), elevated total phytoplankton biomass (as chlorophyll *a*) and dominance of cyanobacteria, reduced water transparency, hypolimnetic anoxia and frequent cyanobacterial blooms, remedial actions to mitigate eutrophication of water bodies in the LVB need to be explored.

3.6.8. Key facts on algal diversity

i) Algae form the basis of the aquatic food chains;
ii) A comparison of data collected in 1960s with that collected in 1990s up to 2000s shows that factors that affect algal biodiversity have changed.
iii) Algal composition changed from dominance of diatoms such as *Aulacoseira (Melosira)* to nitrogen fixing cyanobacteria of the genera *Cylindrospermopsis* and *Planktolyngbya* some of which have the capacity to produce phytotoxins (algal toxins);
iv) Phytoptankton primary production has more than doubled;
v) Algal biomass increased four times;
vi) The diatom composition changed from dominance of *Aulacoseira (Melosira)* to *Nitzischia*;

3.7. AQUATIC INVERTEBRATES' DIVERSITY

3.7.1. Introduction

Freshwater invertebrates are generally small organisms characterised by lack of a backbone. In the Lake Victoria basin, two size categories of invertebrates are recognised; the micro-invertebrates or zooplankton with a body length up to 1.5 mm and macro-invertebrates or macro-benthos with body size greater than 1.5 mm. Zooplankton include most freshwater crustaceans and the rotifers while macro-benthos are constituted by molluscs (water snails), dipteran or lake fly larvae, nymphs of various aquatic insects and the freshwater prawns (*Caridina nilotica*). Zooplankton are pelagic i.e. live suspended in the water column while macro-benthos are associated with bottom sediments. A few groups such as the freshwater prawn and midge larvae are partly benthic and partly pelagic. In the Victoria Basin, zooplankton are dominated by copepods and rotifers while dipteran larvae and molluscs are the more dominant groups in benthic communities.

3.7.2. The composition and diversity of invertebrates

The zooplankton in the LVB are composed of Copepoda and Cladocera (water fleas) while non-crustaceans consist of Rotifera/Rotatoria (wheel animacules). Copepoda is constituted by cyclopoids, calanoids (diaptomids) and harpacticoids. Each sub-category contains several genera and species. Of the three cyclopoid genera (*Thermocyclops, Mesocyclops,* and *Tropocyclops*). *Thermocyclops* is the most diverse genus containing up to four species (*T. emini, T. neglectus, T. oblogatus,* and *T. incisus*). On the Kenyan side of the lake, additional cyclopoid species reported are *Thermocyclops hyalinus* and *Microcyclops* sp. *Mesocyclops* and *Tropocyclops,* each constituted by two species: *M. aequatorialis* and *M. major;* and *T. confinnis* and *T. tenellus* respectively. On the Kenya side, *M. leukarti* has been reported although existence of the species in the African biogeographic area is refuted by some authors. Calanoids comprise two genera each with a single species, *T. galeboides* and *T. stuhlmanni.* In the Kenyan waters, *T. banforanus* and *T. neumanii* have been recorded. Cladocera is typified by several genera; *Moina, Daphnia, Ceriodaphnia, Bosmina, Diaphanosoma, Cydorus, Alona, Macrothrix* with the majority having one species except *Daphnia* which has two: *D. longispina* and *D. lumholtzi*. On the Kenyan side of the lake, additional species of Cladocera such as *Ceriodaphnia rigaudi, Hyalodaphnia barbata* and *Moina macruorus* have been reported. Rotifera is the most diverse group among the zooplankton of the LVB characterised by many genera (e.g. *Brachionus, Filinia, Lecane, Eiphanes, Euclanis, Keratella, Polyarthra, Hexarthra, Synchaeta, Asplanchna, Aneuropsis, Trichocerca, Epiphanes, Pompholex, Polyarthra, Ascomorpha, Beuchampiela, Platyias, Testudinella,* and *Macrochaetus*) and species.

Macro-invertebrates in the LVB consist of insect larvae; mainly two midge types: *Chaoborus* and *Chironomus* spp.; insect nymphs including Diptera, Trichoptera, Hemiptera, Ephemeroptera, Coleoptera, Odonata, Plecoptera; several genera and species of molluscs belonging to two major groups: Gastropoda and Bivalvia; crabs (*Potamon* spp.), freshwater prawns, *Caridina nilotica;* parasitic form copepods (*Ergasilus* sp., *Dolops* sp. and *Argulus* sp.), seed shrimps (ostracods), oysters and aquatic worms, oligochaetes.

3.7.3. Values of aquatic invertebrates

Aquatic invertebrates form the link in the aquatic food web between the primary producers (algae and macrophytes) to higher organisms especially fish. Most larval and juvenile fish, feed on aquatic invertebrates and some fish species depend on aquatic invertebrates throughout their life. Some invertebrates feed on bottom decomposing organic matter and assist in removing materials that would degrade the aquatic systems and assist in recycling of nutrients through feeding on bottom sediments. Grazing on algae improves water clarity. The abundance of large-bodied cladocerans and calanoids provides an indication of the level of fish predation. Some Chironomidae and Oligochaetae species serve as indicators of environmental degradation, just like the extraction of Ephemeroptera, Plecoptera, and Tricoptera from flowing waters.

3.7.4. Threats to aquatic invertebrates

The main threats to aquatic invertebrates in the LVB are predation, environmental degradation due to pollution and eutrophication and loss of suitable habitats.

Many predators selectively feed on certain invertebrate prey owing to morphological features, body size, energy returns and other attributes. As such, selective predation may considerably reduce stocks of the preferred prey organisms and consequently alter the size structure of the prey organisms, often resulting in abundance of small-bodied species of lower nutritional value.

In Lake Victoria, increased predation pressure by high stock sizes of planktivorous dagaa/omena/mukene since the 1980s does not seem to have greatly affected the ecological value of the zooplankton due to the high resilience of copepods which bear most of the predation pressure; although close scrutiny has revealed significant reduction in abundance of large-bodied calanoids and daphnids especially around shallow inshore areas. Parallel reduction/removal of certain trophic groups of fish has left some invertebrates including molluscs, chaoborids and chironomid larvae not fully utilised.

Lake Victoria has gradually undergone changes in water quality alongside an increase in the human population and economic activities (e.g. commercial agriculture, livestock grazing, urbanisation and industrialisation) in the catchment area over recent decades. As a result, toxic-laden effluents, gases and other materials have had impacts on the watershed and air shed of the Victoria basin. The effects on water quality (eutrophication and pollution) are believed to be key drivers of change in the various biological components including invertebrate organisms. Such changes include reduction in abundance of categories of macro-benthos in highly polluted areas of the lake such as the Murchison and Kisumu bays, which are close to urban centres.

Prolonged low oxygen levels have become a common feature in Lake Victoria as the lake has become eutrophic over past several decades. Primary production has increased tremendously leading to frequent algal blooms, associated with oxygen deficit (< 2 mg/l) and fish kills. Prolonged low oxygen conditions especially in the bottom water layer of deep waters is a key stress factor affecting benthic macro-invertebrates and bottom dwelling fishes, which results into periodic loss of habitat.

Marginal vegetative habitats along the shoreline are reservoirs of biodiversity due to their complex, highly structured nature. They serve as a safe haven for a wide range of invertebrates, fishes, reptiles, birds and amphibians. However, many shoreline areas have lost their pristine nature and biodiversity value due to human encroachment on the riparian zone involving vegetation clearance and habitat alteration.

The 2005-2006 period was marked by a severe and prolonged drought that resulted in phenomenal reduction of water level in lakes and rivers in the LVB. Marginal habitats were most affected as they were laid bare by the receding water. Aquatic organisms living in shoreline habitats were deprived of their preferred habitats resulting in high mortality.

3.7.5. Trends in aquatic invertebrate communities in the LVB

Comparison of historical and modern zooplankton data has indicated changes in dominance from the large-bodied calanoids and cladocerans to smaller-sized cyclopoids (Fig. 3.7.1). Also, two zooplankton species, *Ceriodaphnia dubia* and *Simocephalus vetulus* both recorded during the mid-1950s appear to have become extinct as they have not been encountered in the recent collections. Sediment core analysis has also revealed decline of two cladoceran groups, *Bosmina longirostris* and chydorids. However caution should be exercised concerning probable extinction of aquatic invertebrates in the basin because there is a shortage of knowledge and skills on the systematics of many organisms.

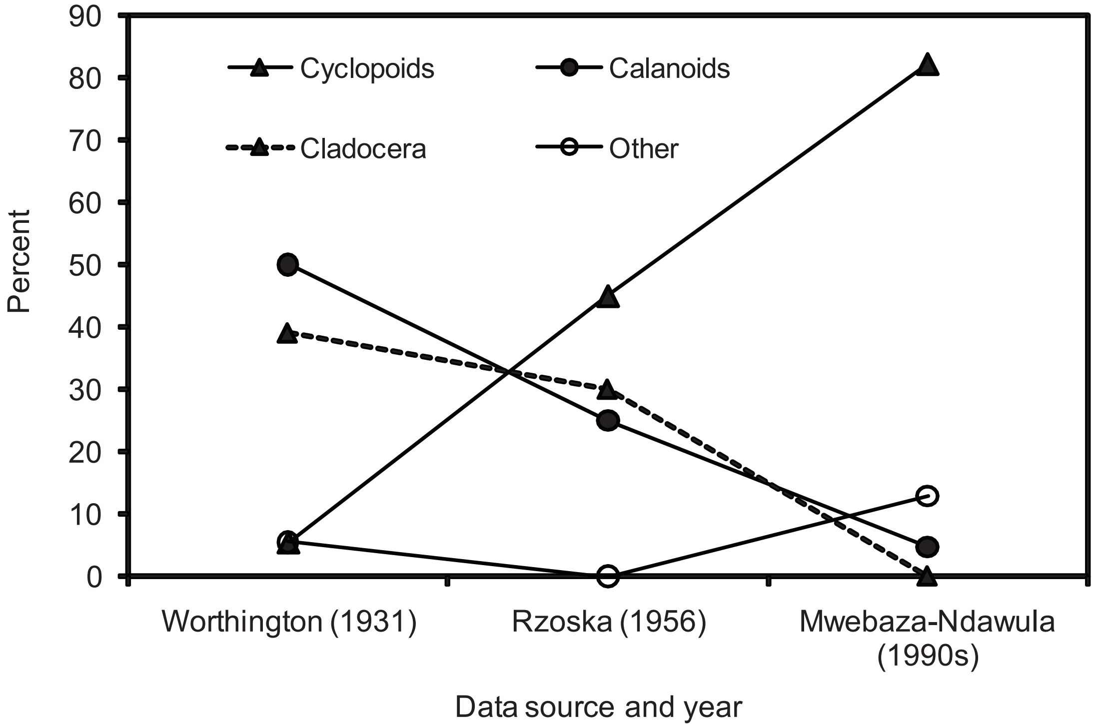

Figure 3.6.1. Changes in percent composition of three key zooplankton taxonomic groups at an open lake station in Northern Lake Victoria between the 1930s and 1990s.

Abundance data collected over the period 1993 to 2005 from the northern part of Lake Victoria indicate no marked year-to-year variations among the various broad taxonomic groups and total zooplankton (Fig. 3.6.2) in the recent past. The spike of high total abundance for the year 1995 is partly attributed to high variation in density estimates of Cyclopoida. Density variations in other years were within narrow limits suggesting stable standing crops of zooplankton over time.

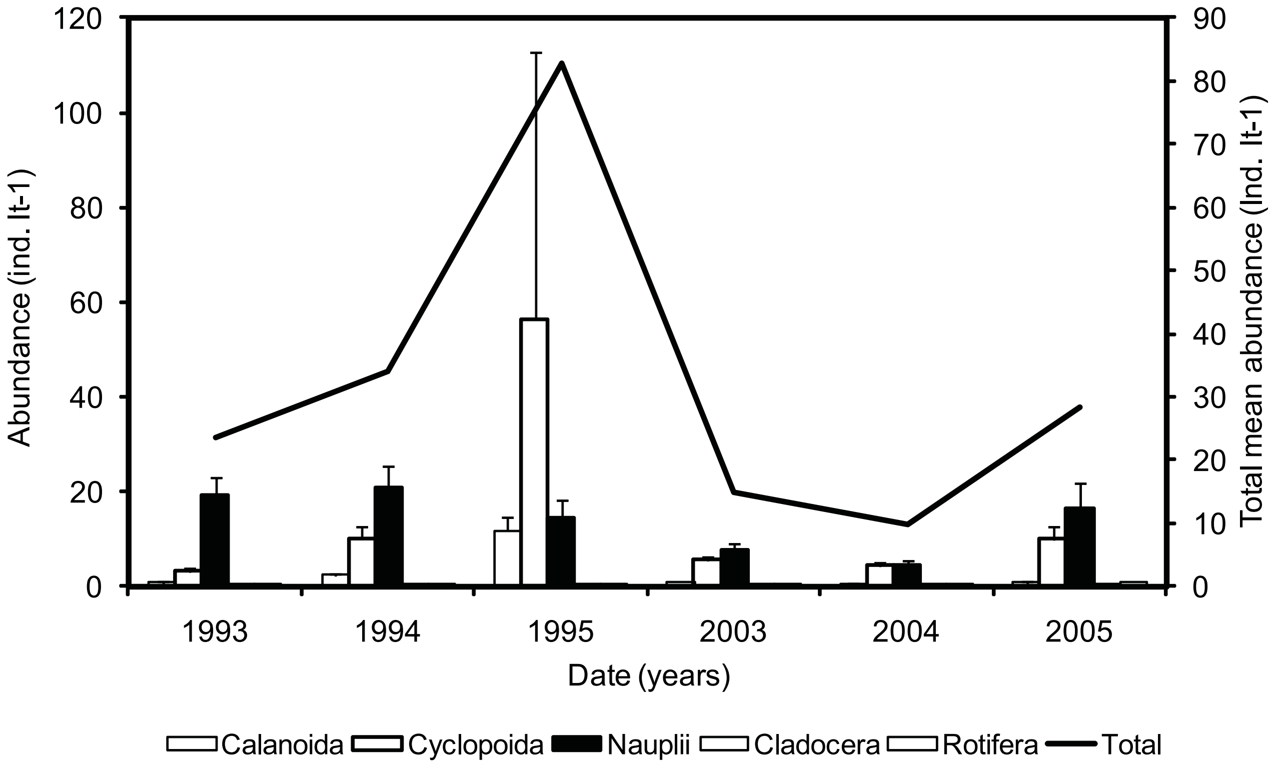

Figure 3.6.2. Trends in mean abundance estimates of zooplankton in Ugandan waters of Lake Victoria, 1993 – 2005.

Caridina nilotica has increased in abundance in Lake Victoria over the last two decades in response to increased detritus food materials resulting from excessive primary production and decline of haplochromine stocks. Substantial reduction of phytophagous fishes has contributed to accumulation of detritus materials used by *C. nilotica* as the main food item. Therefore, the detritus food chain has become increasingly important in Lake Victoria food web.

Molluscs have increased following the near extinction of the mollusc-eating haplochromine fishes in the lake. Huge amounts of mollusc shells are frequently deposited along the lake shores by wave action. Lake fly abundance has also increased substantially. Such changes are associated with corresponding alterations in environmental conditions including eutrophication, pollution, increased and prolonged thermal stratification, anoxia and shifts in fish communities.

Abundance estimates for two dipteran groups, chaoborid and chironomid larvae, in two comparable areas, Ekunu bay and the north-western part of the Uganda waters of Lake Victoria indicate substantial increase of both groups between the 1950s and 1990s. The chironomids and chaoborids show a seven-fold and three-fold increase respectively between the 1950s and 1990s. The abundance data for the highly polluted Murchison bay collected in the 1990s and 2006 show strikingly low levels of the two dipteran groups. Similar trends are observed in the polluted areas in Kenya (e.g. Kisumu) and Tanzania (e.g. in the Mwanza area).

The reported changes in invertebrate abundance are related to the significant reduction of predator fish stocks, which used to feed on these organisms prior to the establishment of the Nile perch in the lake, while the current low abundances in Murchison bay appear to manifest impacts of severe pollution.

3.8.6. The status of aquatic invertebrates

Two cladoceran species*, Simocephalus vetulus* and *Ceriodaphnia dubia* recorded during the mid 1950s, have not been reported in recent collections. It is however not clear if extinction of these has occurred or not. Members of the cladoceran species, *Daphnia lumholtzi* are highly vulnerable to predation by pelagic fishes on account of their relatively large body size and poor escape behaviour. This species occurs in two forms: the smaller helmeted form common in the shallow areas of the lake and the larger round-headed 'monacha' form occurring in deep offshore areas. The spatial separation of the two forms is a manifestation of intensive predation by fish in the shallow inshore areas of the lake.

Cyclopoid species in general are currently under intensive planktivory by the greatly increased dagaa/omena/mukene (*R. argentea*) in the lake. However the zooplankton abundance data collected so far indicate no significant predation threat to these copepods. On the other hand, the stock size of the planktivorous mukene is currently on the increase in Lake Victoria.

Recent studies in the LVB have revealed a preponderance of stenotopic and euritopic populations composed of *Chironomus* sp. and rat-tiled maggots. Such resilient communities indicate poor water quality conditions. Thus the majority of invertebrate species, in polluted areas of the lake including the Murchison Bay in Uganda, Winam Gulf in Kenya and Mwanza Bay in Tanzania are considered to be endangered.

3.7.7. Gaps in information on aquatic invertebrates

The main gaps in information on aquatic invertebrates

i) No sufficient knowledge/skills in taxonomy of aquatic invertebrates
ii) No historical abundance data for Lake Victoria Rotifera
iii) No archival collections for use as reference materials
iv) Insufficient time series abundance data for comparison with current trends
v) There is no inventory/documentation of invertebrate bio-indicators for environment monitoring

3.7.8. Recommendations to reduce the threats and fill gaps in invertebrates

Aquatic invertebrates are an ecologically important biological component in the Victoria Basin area. Their ecological values, which include fish nutrition and options for environmental bio-monitoring, are vital attributes that require safeguard by all in order to contribute to the preservation of the integrity of the Victoria ecosystem. Comparisons from historical and modern data suggest that although invertebrate communities are generally stable and resilient to environmental change, significant alterations in community structure have occurred over time and have to some extent affected key ecological functions of the two key groups, the zooplankton and macro-benthos. Oxygen depletion in the deep waters and human encroachment of riparian habitats is on the increase, depriving invertebrate and other organisms of critical habitat space. Pollution of inshore areas and bays has caused loss of biodiversity and drastically reduced abundance of key functional invertebrate groups in the affected areas. Therefore, the following actions are recommended:

i) Production of a database on aquatic invertebrates in order to promote better understanding of invertebrate communities and their vital ecological roles and facilitate easy reference and updates for scientists, scholars and other interested parties.
ii) Establishment of a network for invertebrate ecologists in the region in order to share information, and skills on aquatic invertebrate systematics.
iii) There is need to initiate archival collections in research institutions, universities and museums to promote sharing of knowledge on the lake's history on invertebrate and other biological entities
iv) Ecologists and students in the region need to undertake research in the area of bio-monitoring in order promote compilation and documentation of biological indicators of water quality for direct application to the local the East African situations
v) There is need for existing laws to regulate the influx of excess nutrients and pollutants into water bodies in order to minimize further degradation of aquatic systems.
vi) There is need for an aggressive and well coordinated community sensitisation and education campaign in the region in order to promote collective responsibility in preservation of aquatic environment and its living resources.

3.7.9. Key facts about aquatic invertebrates

The key facts about aquatic invertebrates include the following:

i) Invertebrates are ecologically important as food source for fish
ii) Some invertebrates such as *Mesocyclops* sp. (Copepoda), *Asplanchna* (Rotifera), phantom midges/chaoborid larvae (Diptera) and *Turbellaria* are predators feeding on other smaller organisms such as rotifers and nauplius larvae
iii) The short life cycles of most of invertebrates and mud burrowing habits of some groups influence nutrient turnover in aquatic systems
iv) Some invertebrates control biogenic turbidity by grazing on algae and therefore play a role in water transparency
v) Some mollusc species such as *Bulinus* sp. and *Biomphalaria* sp. are health hazards as vectors of human diseases such as Bilharzia
vi) Other groups such as *Dolops* sp., *Argulus* sp. and *Ergasilus* sp. and leeches are parasitic on fishes and other aquatic organisms
vii) Some groups such as the rat-tailed maggots, left-handed snails, red chironomid larvae (blood worms), aquatic worms and rotifers are useful as biological indicators of water quality

viii) Some invertebrates such as the freshwater prawn, *Caridina nilotica,* oligochaetes, zooplankton, midge larvae are cleaners of the environment through feeding on dead decaying organic matter or detritus

ix) The calcium-rich shells of molluscs are of economic importance on the basis for their use in the poultry industry

x) Some invertebrates including species of rotifers and cladocerans find application in aquaculture production as live fish feeds

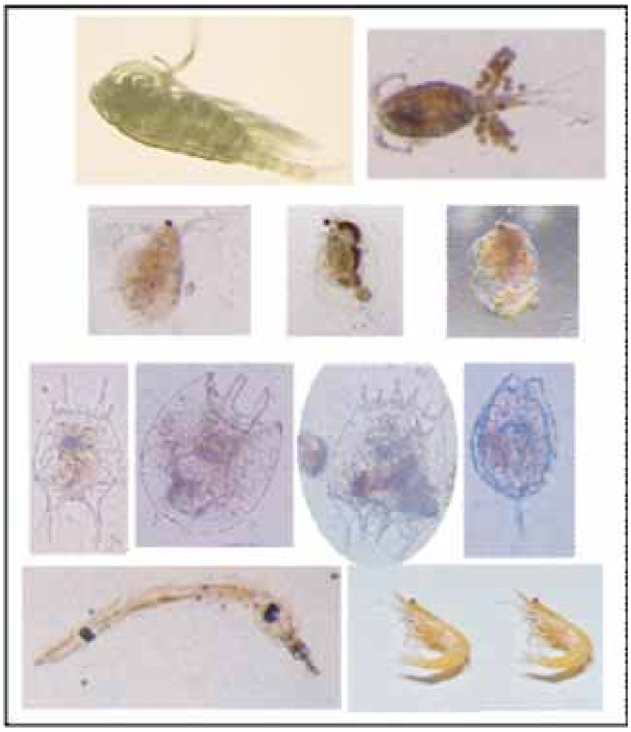

Plate 3.7.1. Key invertebrate groups: from top to bottom: copepods, cladocerans, Rotifers, *Chaoborus* and *Caridina nilotica*

3.8. FISH SPECIES DIVERSITY

3.8.1. Introduction

Prior to 1960s, the LVB had an extremely a high diversity of fish species, with most of them endemic and of economic and scientific value. Apart from the two endemic tilapiine species, *Oreochromis esculentus* and *O. variabilis* that were the most important commercial species in the basin, other species formed a significant part of the fishery. These included P*rotopterus aethiopicus* (lung fish), *Bagrus docmak, Clarias gariepinus, Barbus spp,* mormyrids, *Synodontis spp, Schilbe intermedius* and *Rastrineobola argentea.* The rivers in the Lake Victoria basin also had a number of riverine fish species, of which, the most commercially important were *Labeo victorianus* and *Barbus altianalis*. Haplochromines were the most abundant group of fishes in Lake Victoria and formed about 80% of the biomass during the 1970s. There were more than 500 haplochromine species, 99% of them endemic to the basin and 70 non-haplochromine species. The haplochromines occupied most trophic levels and played an important role in the flow of organic matter in the ecosystem. Up to 11 tropic groups of haplochromine cichlids were identified in the lake.

By the 1960's, stocks of the native tilapiines and other large species of Lake Victoria fish had been reduced by overfishing. Catch rates of tilapia dropped from 50 – 100 fish per 50m long net of 127 mm stretched mesh to less than five fish in the same net. Nile perch and four tilapiine species were introduced into Lake Victoria and several satellite lakes in the Victoria and Kyoga basins in the 1950s and early 1960's, to improve the declining fisheries. As the stocks of Nile perch increased, fish species diversity, especially of the haplochromines, decreased rapidly. The contribution of haplochromines to fish biomass in Lake Victoria decreased from about 80% during the 1970s to less than 1% in the early 1980s. As a result of overfishing and introduction of exotic fishes, populations of most of the native species declined and many species became rare in the main lake and some of the satellite lakes. Many important food fish species were feared to have disappeared. Most notable was the disappearance of over 50% of the 500+ species of the endemic haplochromine cichlids. Lately, both Nile perch and Nile tilapia have rapidly declined mainly due to over-exploitation. The declining trend of these two introduced fish species has been accompanied by the resurgence of haplochromines and an increase in the endemic cyprinid, *dagaa/omena/mukene*.

Following the changes in the fishery a number of management measures were put in place including a ban on beach seines and under-sized mesh gillnets (<127 mm stretched mesh) in 1994 and trawlers in 1996. Although environmental changes and local overfishing played a role in the decline of native fish stocks, the Nile perch predation was the most likely driving key factor. The introduced tilapiines (*O. niloticus, Tilapia zillii, T. rendalli* and *O. leucostictus*) impacted and displaced endemic tilapiines *O. esculentus* and *O. variabilis* mainly through inter-specific competition and hybridization.

3.8.2. The composition and diversity of fishes

A total of 179 fish species belonging to 52 genera and 13 families were recorded from the available data from 17 lakes, while 39 fish species belonging to 24 genera and 14 families were recorded from data on 10 rivers in the basin. The only two wetland ecosystems with fish diversity data indicated existence of 15 fish species belonging to 14 genera and 9 families. Overall 183 fish species belonging to 55 genera, 13 families and seven orders were registered. Out of these, 63 fish species are considered extinct and 85 species are threatened, i.e. 39 species critically endangered, 6 endangered and 40 vulnerable (Table 3.8.1).

Table 3.8.1. The status of fish species in the Lake Victoria basin

	Status							
Country	**Extinct**	**Critically endangered**	**Endangered**	**Vulnerable**	**Near threatened**	**Least Concern**	**Not evaluated**	**Total**
Kenya	54	33	6	37	38	3	1	161
Tanzania	59	35	5	37	32	3		164
Uganda	58	37	5	38	47	4		171
Overall	63	39	6	40	53	4	1	183

Currently the Lake Victoria fisheries are dominated by three main species namely Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus)* and the cyprinid *Rastrineobola argentea.* Apparently, there are indications of stock decline in the large commercial fishes, especially *L. niloticus* and *O. niloticus* and an increase in stocks of the smaller pelagic fish e.g. *R. argentea* and haplochromines. Recent surveys have indicated signs of re-bouncing back in species diversity of species originally thought disappeared. In some lakes in the LVB (e.g., Nabugabo) and some parts of the main Lake Victoria, dramatic increase, and in some cases, reappearance of indigenous species has been noticed. Most notable has been the increase in the biomass of haplochromine cichlids.

The resurging fishes represent only a few trophic groups and a few species that occur in large numbers. The other examples of remerging species in the main lake include *L. victorianus, Schilbe intermedius, C. gariepinus, Synodontis victoriae and S. afrofischeri*. *Oreochromis esculentus* which disappeared from the main Lake Victoria, still form an important fishery in some satellite lakes in the Lake Victoria basin e.g. lakes Kanyaboli (Kenya), Ikimba (Tanzania) and Koki lakes (Uganda). The riverine fish species (*S. intermedius, L. victorianus, Synodontis spp* and *Brycinus spp*.) which were abundant before Nile perch explosion are still present but with reduced stock size as result of predation in the main lake and overfishing at the river mouths.

3.8.4. Trends in fish catches

Assessment of fish catch trends for most water bodies in the Lake Victoria basin is difficult because of poor or non-existent data except for Lake Victoria which has some intermittent data dating as far back as the 1960s. After 1960, the countries sharing Lake Victoria collected fish catch statistics individually with different data recording systems and levels of consistence until 2005 when catch assessment surveys were harmonized for the whole lake. The trend in annual fish catches in the country waters are explored from these data sets (Figure 3.8.1).

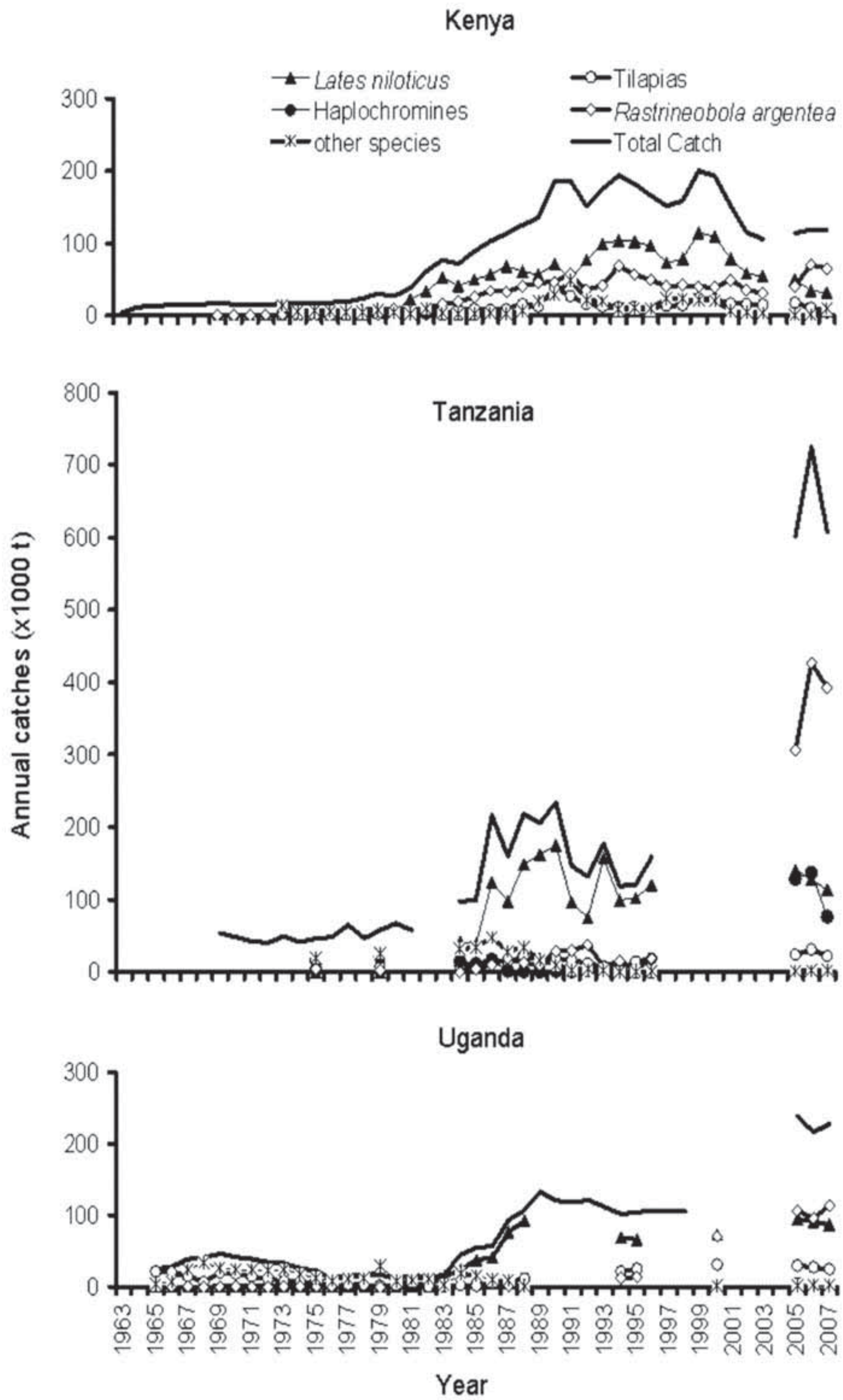

Figure 3.8.1 Trends of Fish catches in the Kenya, Tanzania and Uganda parts of Lake Victoria between 1963 and 2007.

Given the intermittent country data sets the accuracy in depicting lake wide trends is uncertain, but Figure 3.8.2 provides an impression of the main changes in catches and fishing effort in the lake since the 1960s.

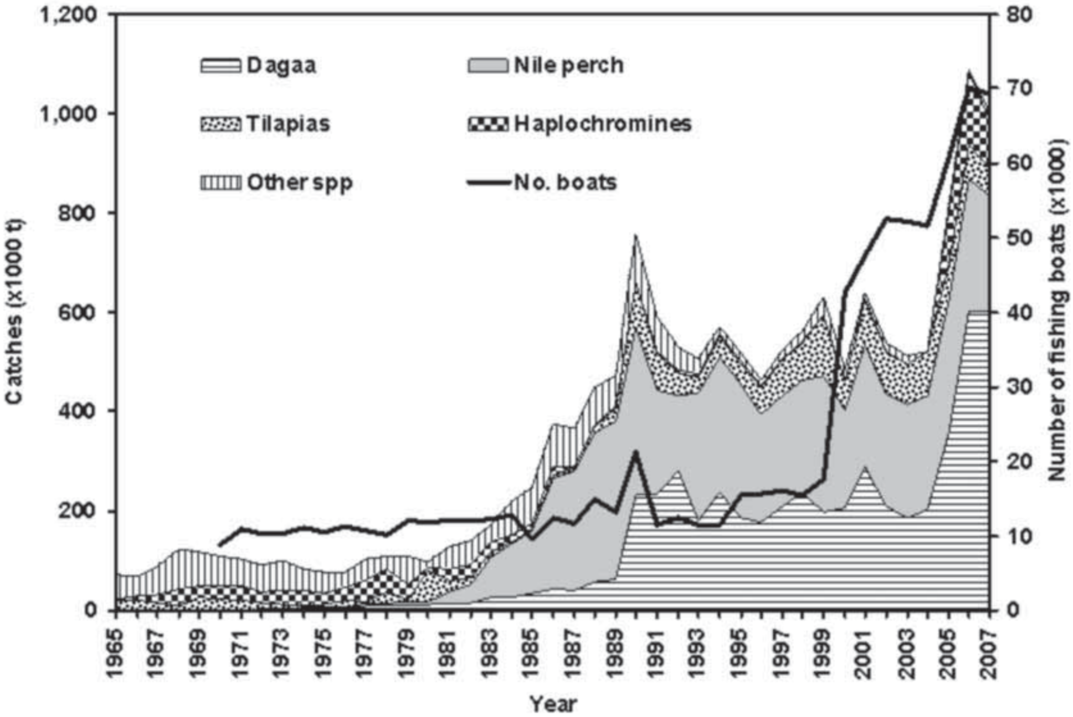

Figure 3.8.2 Lake wide trends in fish catches and fishing effort (number of fishing boats) in Lake Victoria between 1965 and 2007.

Commercial fishing in Lake Victoria followed the introduction of nylon gillnets in 1905. The main target fish species were two endemic tilapias, *O. esculentus* and *O. variabilis* but the catches of other large fishes, *B. docmak, C. gariepinus*, *P. aethiopicus, L. victorianus, Burbus* spp and mormyrids were also important. The tilapia catch rate in 5 inch mesh gillnets in 1905 was 50 to 100 fish per gillnet but this decreased to about 6 fish per net by 1927. By the 1950s, populations of the native tilapia, the main species supporting the fishery, had decreased to very low levels following the intensification of the gillnet fishery. To boost tilapiine production, four alien species, *O. niloticus, O. leucostictus, T. zillii* and *T. rendalli* were introduced into the lake in the mid 1950s and early 1960s. In addition to the tilapiines, Nile perch (*L. niloticus*), was simultaneously introduced. The Nile perch started dominating the catches from the early 1980s.

Along with considerable increase in Nile perch catches, landings of all other species decreased except *O. niloticus* and dagaa (*R. argentea*). The total fishery yield increased considerably from less than 100,000 t year^{-1} in the early 1970s when Nile perch started appearing in the catches, to approximately 400,000 t in the second half of the 1980s. The total catches oscillated around 550,000 t throughout the 1990s to early 2000. Data collected in 2005 to 2007 show a two fold increase in the catches of *R. argentea* compared with the catches in the 1990s while the catches of Nile perch more or less decreased. Over the same period, large quantities of pelagic haplochromines were recorded in the catches, especially in the Tanzanian part of the lake. From 2005 to 2007 the annual catch of all fishes increased to around 1,000,000 t with 70% contributed by small pelagic species (*R. argentea* and haplochromines), 24% by the Nile perch and tilapia about 6% while all other species contribution at less than 1%.

The systematic lake wide frame surveys conducted between 2000 and 2008 indicated rapid growth of fishing effort from around 42,000 to 70,000 fishing boats. Similar large increases were registered in other elements of fishing effort, e.g. numbers of fishers and gillnets accompanied by increase in use of illegal destructive fishing gears especially beach seines. The number of boats was less than 18,000 through the 1990s. Similar trends appear to have occurred in the satellite lakes.

3.8.5. Trends of fish stocks

The first survey of the lake (1927 – 1928) did not estimate the actual biomass but indicated that the commercial fisheries depended on two native tilapiine cichlids (*O. esculentus* and *O. variabilis*). The trends in fish stocks of Lake Victoria are derived from surveys conducted by EAFRO with the support of UNDP from 1969 to 1974; that by LVFRP from 1995 to 2002; and that by IFMP from 2003 to 2008.

Trawl data

Long-term comparable data sets from bottom trawl surveys dating as far back as 1969 are available for the Tanzanian and Ugandan parts of Lake Victoria which constitute 94% of the lake. The trends of standing stock (Figure 3.8.3) indicate dominance of the haplochromine cichlids from the late 1960s to early 1980s in the Ugandan waters and up to the mid 1990s in the Tanzanian part of the lake. The decline of the haplochromines coincided with a rise in the Nile perch standing stock. The Ugandan data indicate a continuous decrease of Nile perch standing stock from 1999 to 2008, although the Tanzanian part suggests an increasing trend over the same period. There is no clear explanation for the apparent increasing Nile perch standing stock in the Tanzanian part of the lake against a significant drop in Nile perch biomass shown by Hydro acoustic surveys and the decreasing trend of catches depicted by Catch Assessment Surveys over the same period. It appears the trawl surveys in the Tanzania waters concentrated in highly productive shallow waters leaving out deeper open waters which constitute the largest part of the lake in Tanzania possibly resulting in a false impression of increasing Nile perch standing stock.

Hydro-acoustic data

The recent estimate of the lake wide mean fish biomass of the three major fish taxa (Nile perch, *R. argentea* and haplochromines) in Lake Victoria is based on the six acoustic surveys conducted under IFMP in 2005 to 2008 (2.05 ± 0.18 million tones). This figure is close to the 2.10 ± 0.13 million tonnes estimated from the five LVFRP surveys in 1999 to 2001 (Figure 3.8.4). Thus, the total biomass of the three major taxa in the lake has not significantly changed for a period of almost 10 years, i.e. 1999 – 2008. What have evidently changed are the biomass proportions of the three major fish groups in the system. The Nile perch biomass dropped from 1.9 million tonnes (82.9% of the total biomass) to 0.37 million tonnes (14.2%) between August 1999 and February 2008. Conversely, the dagaa biomass increased from 0.25 million tonnes (10.5%) to 1.48 million tones (57.3%) over the same period. Considering only the recent surveys conducted by IFMP, the dagaa biomass has increased three fold from 0.49 to 1.48 million tonnes in a period of less than three years (August 2005 – February 2008). Over the same period, the biomass of haplochromines and other minor fish groups also increased from 0.44 to 0.73 million tones.

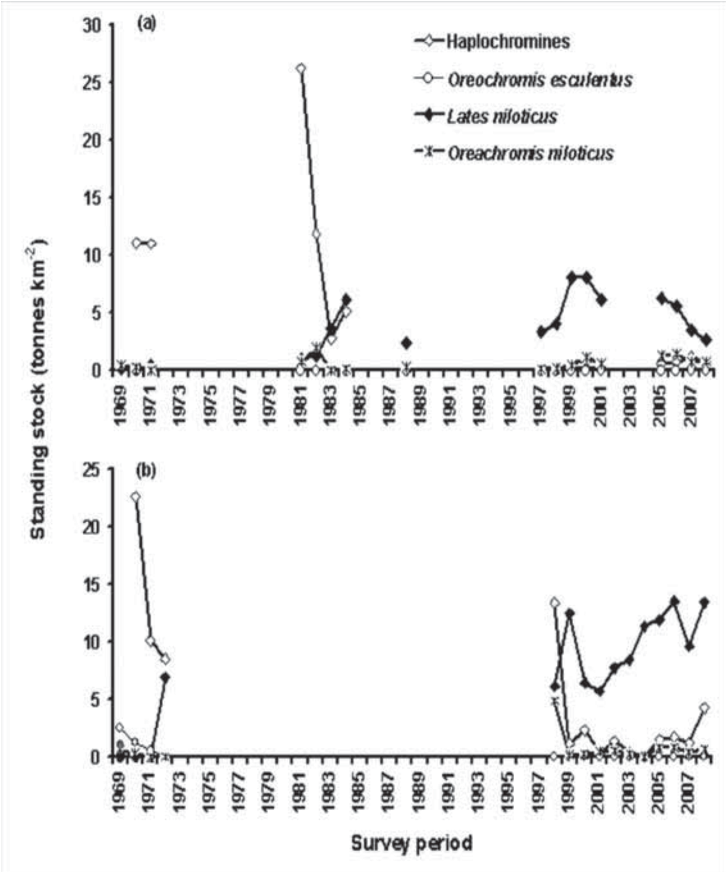

Figure 3.8.3 Trends in standing stock of the major fishes in Lake Victoria based on bottom trawl surveys between 1969 and 2008 (Surveys EAFFRO/UNDP, LVFRP II, and IFMP) in (a) Ugandan waters and (b) Tanzanian waters

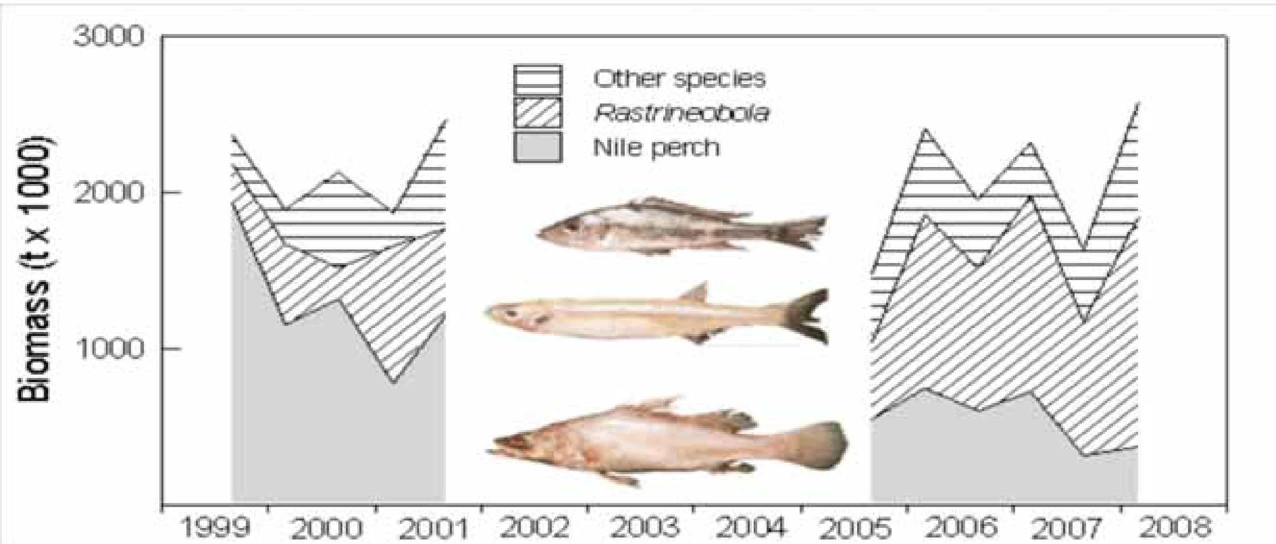

Figure 3.8.4 Estimated biomass of the three major fish taxa in Lake Victoria in 1999 to 2008.

The threats to fish species diversity

The threats to fish species can be grouped into five interacting categories. Over-exploitation; introduction or invasion of exotic species; pollution and eutrophication; flow modification; destruction or degradation of habitat; and climate change.

Over exploitation is the result of harvesting or killing animals or plants, for food, materials or medicine, over and above the reproductive capacity of the population to replace itself. Over-exploitation is one of the threats that mainly affect fishes whereas the other five categories have consequences for all freshwater biodiversity ranging from microbes to mega fauna. Overexploitation has been the dominant threat to aquatic biodiversity and overfishing has devastated many commercial fish stocks. Overfishing reduces the size and genetic diversity of affected fish population. This decline has been found to reduce reproductive success and increase susceptibility of stocks to disease and environmental stresses. The problem of by catch of non-target species and under-sized juveniles of target species caught sometimes exceeds the saleable sizes. Overfishing can also lead to complete collapse of the target species and an ecosystem as a whole, termed as a trophic cascade. By 1950s and 1960s there were already signs of overexploitation of the larger fish species i.e. *O. esculentus, O. variabilis, L. victorianus, B. docmak, Mormyrus kannume* and Lung fish). By the late 1960s the catches were dominated by the less preferred small fish the haplochromines. Besides the main lake, high-value fish species such as *L. victorianus* in the rivers in the basin were fished to near extinction in the 1960s.

Pollution from point and non-point sources arising from land based activities leads to contamination of the lake with heavy metals and pesticide residues. Pollution also comes from industries, agriculture as well as households, either by direct disposal of harmful substances into the water bodies or indirect discharges that reach the lakes via rivers. Persistent organic pollutants consumed by organisms at the bottom of the food chain get concentrated as predators eat contaminated prey. The problem of pollution is pandemic especially around parts of the lake located near urban centres like Murchison Bay near Kampala city in Uganda, Nyaza Gulf near Kisumu city in Kenya and Mwanza Gulf near Mwanza city in Tanzania. The threat of excessive nutrient enrichment and other chemicals such Mercury is a reality. Despite the growing pollution threat there are currently no targeted efforts to reduce water pollution from domestic and industrial point sources,

Habitat degradation is brought about by an array of interacting factors. It may involve direct effects on the fish habitat such as sand excavation or indirect impacts which are already evident, e.g. the high human population density in the basin leads to accelerated conversion of forests to agricultural land. The consequences of this include increased surface runoff and river sediment loads that can lead to habitat alterations such as shoreline erosion, smothering of littoral habitats, clogging of river bottoms or wetland aggradations.

Reduction in water levels in water bodies is another threat to fish diversity in form of habitat reduction. For example historical natural water level fluctuations, due to changes of climate and river discharge into Lake Victoria, may have short and long-term impacts. Short-term impacts include seasonal or wind-induced changes of water level. Seasonal changes of water level of the lake can reach almost *0.5* m, whereas under the influence of surges, it can rise *1.5-2* m. In the west of the Eastern side of Lake Victoria, surges (El Nino) cause inundation of the coastline up to 50 m onshore, while retreats cause exposure of *20*m of the lakebed. From late 2000 to 2005, the level of Lake Victoria receded on the coastline by an average of *5* m reducing fish habitats in the littoral areas and posing potential negative impact on fish diversity. Shallow bays such as Kusa and Kendu in Kenya have dried and the river delta of Nyando Awach has reduced significantly.

Flow modifications are common in running waters and this is not an exception to the Lake

Victoria basin. Regulation of rivers that flow into Lake Victoria could be one of the most significant anthropogenic impacts on the biodiversity of the lake. From the period of the 1970s to the 2000, dozens of reservoirs (e.g. Panpaper, Mumias, Muhoroni, and Chemilil) were built on rivers flowing into Lake Victoria for purposes of agricultural irrigation and hydroelectric power generation. Regulation of river flow has both chronic and acute impacts. Changes in the hydrological regimes, reducing spring run-off, can lead to increased shoaling of river delta and reduction in the area of delta vegetation (reeds, cat-tail, and bushes). This loss of vegetation can result in a loss of aquatic fauna and many migratory and semi-migratory species are deprived of their natural spawning grounds. As spring flows are reduced, fish migration upriver for spawning is impeded and essential nursery areas are limited.

Wide spread invasion and deliberate introduction of non-indigenous species adds to the physical and chemical impacts of humans to fish species diversity, in part because exotics usually successively invade native species already modified or degraded by humans e.g. the introduction Nile perch and four tilapiine species in the basin provides a classic example. Escape of farmed fish into the wild is also associated with this phenomenon.

Climate change has started manifesting of recent and its impacts can easily be depicted e.g. the current water fluctuation levels in water bodies. Climate change is associated with the continuous global increase in temperature and green house gas emissions. The global extent of climate change will mean that no ecosystem on earth will be immune from rising air or sea temperatures or changing weather patterns. The impact of climate changes on fish diversity in the basin is not yet well understood, but generally increase in ultraviolet radiation due to ozone depletion harms microscopic, photosynthetic algae and zooplankton at the base of the aquatic food web, potentially affecting the food supply of the entire water body community. Climate change may not only result in water level rise and severe storm damage but also temperature, salinity and other parameters causing a wide range of effects from species mortality, modifying species composition and migratory patterns to shifts in the entire aquatic system. However, the impact of climate change on biodiversity may be gradual compared to other threats.

3.1.6. Conclusions

i) A thorough evaluation of the status of aquatic biodiversity in the LVB requires significant amount of data sets covering the main lake, all the satellite lakes, rivers and wetlands. In the course of this study it has been realised such data are lacking, inadequate, or inaccessible.
ii) Fish species in the LVB form an important resource whose commercial and nutritional value can be easily assessed and appreciated.
iii) Threats to fisheries in the Lake Victoria basin are mainly anthropogenic although some are magnified by extraneous natural phenomena like climate change. The major threats to the fisheries are overexploitation; water pollution; flow modification; destruction or habitat degradation; introduction or invasion of exotic species and climate change.
iv) Some fish species such *O. esculentus* that disappeared from the main Lake Victoria are still present in some satellite lakes like Ikimba, Kanyaboli, and Nawampasa.
v) Approximately 63 fish species in the basin are considered extinct while close to 85 species are threatened. The threatened species could as well disappear if no efforts are put in place to protect and preserve them.
vi) Estimates of fish catches and standing stocks on the main Lake Victoria show continu-

ous reduction in the large species (Nile perch and Nile tilapia) while the small pelagic species (*R. argentea* and haplochromines) are increasing.

3.8.8. Recommendations to reduce threats and fill gaps

i) There is need to put all the available data sets on fish diversity into an accessible database updated regularly with data from regular monitoring surveys.
ii) A database of the types, uses, values and threats of the various fish species in the basin should be maintained.
iii) Efforts should be made to reduce on major threats to the fisheries of the basin especially the man-made ones such as over-exploitation. This can be achieved through controlling fishing effort and ensuring sustainable harvest of mature fishes.
iv) Satellite lakes in the basin that still contain the fish species that have disappeared from the main lake should be clearly identified and gazetted as conservation areas to control exploitation and provide natural reservoirs of the endangered species.
v) Some parts of the main lake that support high fish species diversity should be mapped and gazetted as conservation/protected areas.
vi) The main threats to fish species diversity in the Lake Victoria basin that should be managed include: fisheries overexploitation, habitat destruction/degradation, water pollution, introduction of exotic species and climate change.

3.1.7. Key facts

a) Major changes in fish species composition and abundance in Lake Victoria, driven by local overfishing and to some extent environmental changes happened in the first half of the 20th Century leading to collapse of the fishery based on the native tilapiines *O. esculentus* and *O. variabilis*.
b) The Nile perch and four tilapiines (*O. niloticus, Tilapia zillii, T. rendalli* and *O. leucostictus*) were introduced into the lake in the late 1950s and early 1960s to rejuvenate the fisheries.
c) The commercial fishery changed from a multi-species native fishery to one dominated by three species with two introduced (*L. niloticus* and *O. niloticus*) and the native small pelagic minnow (*R. argentea*).
d) In the early 1970s during the initial appearance of the Nile perch in the catches, more than 80% of the fish biomass in Lake Victoria was haplochromine cichlids of which more than 99% were endemic.
e) The annual fish yield of Lake Victoria around 1970 was less than 100,000 t but thereafter rose to a peak of around 550,000 t around 1990 with Nile perch contributing about 70% of the catches.
f) Throughout the 1990s, similar quantities of Nile perch and *R. argentea* were landed from Lake Victoria.
g) Recent estimates in 2005 to 2007 show that the annual fish catches in Lake Victoria have increased to approximately 1,000,000 t of which the small pelagic species (*R. argentea* and haplochromines) contribute 70%, Nile perch 24%, tilapia 6% and other species less than 1%.
h) The recent changes in fish catches have been accompanied by rapid growth of fishing effort, e.g. fishing boats increased from 18,000 in 1990s to 42,000 and 70,000 in 2000 to 2008.
i) Over the last 10 years the total biomass of fish in Lake Victoria has remained approximately the same at around 2 million tonnes.

j) The Nile perch biomass in Lake Victoria decreased sharply from 1.9 to 0.37 million tonnes from 1999 to 2008 respectively whereas the *R. argentea* biomass increased from 0.25 to 1.48 million tonnes over the period.

k) Over the last three years alone there was a three fold increase of the *R. argentea* biomass in Lake Victoria from 0.49 to 1.48 million tonnes in August 2005 to February 2008 respectively.

l) Currently, 183 fish species belonging to 13 families are estimated to inhabit lakes, rivers and wetland ecosystems in the LVB compared with over 500 species 40 years ago.

m) Of the 183 fish species listed, 63 fish species are considered extinct and 85 species are threatened.

n) Recent surveys have indicated signs of resurgence for some fish species especially the haplochromine cichlids in the main lake and satellite lakes.

3.9. DIVERSITY OF NON FISH VERTEBRATES (AMPHIBIANS, REPTILES, BIRDS AND MAMMALS)

3.9.1. Introduction

The LVB harbours a diversity of species of non-fish vertebrates including amphibians, reptiles, birds and mammals of direct and indirect values to humanity. Each of these taxa shows different levels of dependency on the aquatic habitat. Some species require the aquatic ecosystems and its constituent habitats for most of their life cycles while others are occasional visitors to the ecosystem.

Of the three known living orders of amphibians, only one (Anura consisting of frogs and toads) has been recorded in the LVB. Frogs and toads are, however, some of the least studied group of vertebrates in the basin. Four of the known six living orders of reptiles are represented in this basin. These are Chelonia (turtles, tortoises and terrapins); Sauria (lizards including agamas, monitors; chameleons and skinks which include limb-less skinks and geckoes); Crocodilia (crocodiles, alligators and gavials); and Serpents (all types of serpents commonly known as snakes); There are no members of orders Rhynchocephalia and Amphisibaenia in the Lake Victoria Basin.

Published information on the species richness and abundance of water birds in the Lake Victoria basin is still scanty, partly due to limited bird specific research in the basin. The birds use aquatic systems as their habitat and sources of food. The high mobility of birds enables them to move away from unfavourable environments. Changes in abundance and distribution of birds therefore provide an indication of environmental health. Waterfowl are among the top predators in freshwater ecosystems. The kingfisher, the cormorants and pelicans for instance, feed on fish. Some birds like gulls and sterns can give local fishermen an indication of suitable fishing grounds. Several bird species of special conservation status have been recorded in the LVB. Some Important Bird Areas (IBAs) have been recorded in the LVB. These include: the Mburo-Nakivali wetlands, the Sango Bay – Musambwa Islands of Kagera wetlands, the Nabugabo wetlands, the Nabajjuzi wetlands and the Mabanba wetlands.

Studies on mammals in the LVB have concentrated on the larger forms such as hippos, elephants, buffaloes, and lions etc. While many of the mammals in the basin live on land; others live in trees and others live in tunnels underground. The most commonly cited mammalian fauna associated with wetlands have been the Sitatungas, some primates, hippos and otters. Small mammals that also occur in this habitat have rarely been documented.

3.9.2. Composition and diversity of non-fish vertebrates

Most information on birds in the LVB is based on field studies in Uganda. A total of 27 amphibians, 18 reptilian and 40 mammalian species have been recorded in selected sites of the LVB in Uganda. Lake Nabugabo was the most species rich site for amphibians with 25 species followed by Victoria (12) and Wamala (12), Kachera (7) and Wamala (8). These areas has been estimates to have 45 species of amphibians.

Lake Nabugabo has the highest reptile richness with 15 species followed by Victoria sites (12), and Wamala (4). The maximum number of reptile species in this region is estimated at 29.

Lake Nabugabo again ranks highest in the number of mammals (35 species), followed by Victoria (19), Kachera (5), and Wamala (6). The number of mammals in the region is estimated to be 81 species.

A total of 217 species of birds have been recorded in the LVB: Uganda (81), Kenya (73), and Tanzania (63). In Uganda the highest number of species has been recorded in Lake Wamala (62), followed by Nabugabo (61).

Most of the bird species are associated with wetlands, others with forests or grassland species and a few species occur in open waters of the lakes. The choice of bird habitat is related to:

i) The activity to which a particular habitat is put. For instance forested habitats were very important for resting but not feeding.
ii) The structural adaptations of different bird species, for instance the shorebirds were restricted to the areas they used by the depth of the water. They could effectively use those habitats with the water depth less than their tarsus length.
iii) The behaviour of the particular species especially while foraging, for example the cormorants and pelicans can only feed from water.

The similarity in bird species diversity of Victoria basin lakes is shown by Bray-Curtis analysis (Table. 3.9.1). Wamala and Victoria are closely similar in species richness (80%) while Kayanja and Victoria are least similar (31.4%). The position and the size of a lake seem to play a role in bird species distribution according to this analysis

Table.3.9.1. Similarity matrix of bird species diversity in LVB (Uganda)

	Nabugabo	Kayanja	Kayugi	Wamala	Victoria
Nabugabo	*	31.5069	49.3827	88.9796	73.7327
Kayanja	*	*	48.4848	33.557	31.405
Kayugi	*	*	*	48.4848	51.0949
Wamala	*	*	*	*	80
Victoria	*	*	*	*	*

In Tanzania, among bird species recorded in the Simiyu, Rubana, Kitaji and Mwanza Gulf wetlands, Simiyu and Rubana contained the highest number of species totalling 55 and 51 species respectively. Mwanza wetland recorded 30 species while the Kitaji had 33 species. These exclude many wetland birds that do not forage in aquatic areas, e.g. weaverbirds, cisticolas, warblers, and flycatchers.

In Kenya, the dominant families of water associated birds observed in selected Lake Victoria wetlands include: Sternidae 36.1% and Scolopacidae (18.2%). The highest diversities and densities occur at irrigation schemes of Kano. These schemes have been identified as the main feeding grounds for aquatic fowl. Gulls are dominant in the main Lake and in the interface zone while Hamerkops egrets and kingfishers dominate the inshore areas and the littoral fringes.

The benthivores dominate Lake Simbi and the Kano plains while most trophic groups are represented in the Sondu-Miriu wetland with dominance of omnivores. A study of bird populations in selected Lake Victoria wetlands revealed that piscivores dominated in Aneko. River Tako and Pengle while the omnivores dominated in the Rota, Dunga and the Sondu-Miriu. In the Sondu- Miriu wetland the most represented families were Ardeidae (46.8%), Threskiornidae (18.51%) and Sternidae (16.5%).

The Sondu-Miriu river mouth is well storked with fishing birds such as pelicans, cormorants and kingfishers. The wetland also hosts some of Kenya's endemics such as the Papyrus gonolek (*Luniarus mufumbiri*) and the papyrus yellow warbler (*Chloropeta gracilirostris)* both of which are threatened.

Bird distribution is influenced by human activities, availability of food and seasons. Warblers and Cisticolas dominated the papyrus swamps contributing 68 % of the total, the weavers constituted 18.3 % while Papyrus Canary is rare. Among the Warblers, the White-winged was the most abundant Warbler followed by the Greater Swamp Warbler.

Bird species that are endemic to papyrus swamps include the Papyrus yellow warbler (*Chloropeta gracilirostris)*, the Papyrus Gonolek, (*Laniarius mufumbiri)*, the Papyrus Canary (*Serinus koliensis)*, Carruthers's Cisticola (*Cisticola carruthersi)* and white-winged warbler (*Bradypterus carpalis)* all of which are contained in the East African Red Data list of birds. The papyrus-specialist bird species are not evenly distributed. For instance, the Papyrus Yellow Warbler is absent from the more extensive papyrus stands around the northern and western shores of Lake Victoria.

3.9.3. Values of non-fish aquatic vertebrates

Non-fish aquatic vertebrates have both direct and indirect values including pest control, food, medicine, tourism.

Amphibians consume insects and can control pests. Some frogs are edible. Tadpoles serve as food of other aquatic predatory organisms including, birds, snakes, fishes. The African frog *Xenopus* is one of the most widely used laboratory animal. The skins of frogs are sensitive to environmental degradation and their juvenile's can act as indicators of environmental degradation. Skin glands of frogs produce a range of substances used in defence against predation and these have been observed to have pharmacological value. Some antibiotics such as those against *Staphylococcus aureus* are based on amphibian excretions.

Reptiles are an important tourist attraction and varieties of reptiles are kept in zoos. They serve as biological indicators of the environment. Some feed on rodents which could be destructive to man and his crops and others are edible by man.

Birds are a tourist attraction and bird watching is a major recreational activity. The high mobility of birds enables them to move away from unfavourable environments. The changes in abundance and distribution of birds can therefore give an indication of environmental health. For instance the presence and density of Marabou, *Leptoptilos crumeniferus* can give an indication of the poor refuse management of a town. Some birds like gulls and sterns feed on fish and their concentration provide fishermen with information of suitable fishing grounds. Birds are also able to return nutrients to lake ecosystems through deposition of the *Guano*, a nutrient rich form of urea. Water associated mammals like Sitatungas and Hippopotamus are hunted for meat and Sitatunga heads are used as trophies. Other aquatic mammals like Otters and crocodiles are important tourist attractions and are used as pets in zoos.

3.9.4. Threats to non- fish vertebrates

The LVB has experienced increased human population and subsequent activity, which may be harmful to the survival of aquatic and semi-aquatic fauna. Apart from the traditional activities of fishing and trade, other human related activities such as dam construction, fish factories, farming, building of beaches and other infrastructure are on an increase along the shores and within the basin. These activities impact flora and fauna of the region in different ways.

Threats to aquatic birds include: drowning and getting entangled in nets; Loss of feeding, roosting/nesting and breeding grounds; poaching; over-exploitation through trapping.

Drowning/entangling in fishnets

Many aquatic fauna not targeted by fishermen accidentally get entangled in fishnets set in these waters. Birds such as cormorants, ducks and pelicans; mammals such as otters; reptiles such as crocodiles and monitor lizards, foraging in inshore areas, especially along swampy wetlands are occasionally caught in gillnets set to capture fish. Even when recovered alive, these animals are normally killed as they are perceived to be destructive to the fish and the nets.

Habitat loss/destruction

Many water related fauna utilize vegetation cover around the lake as hiding, feeding, breeding and as roosting sites. These habitats are continuously being degraded by human activities. Along the lake, burning is widely practiced in wetlands by farmers, pastoralists and hunters for agriculture, grazing and hunting. Pastoralists burn rangelands to stimulate growth of pasture. Many plant species are cut down for various human needs such as: building, medicines, cooking or simply as defensive mechanisms against pests. Chopping down large trees among other reasons deprive some birds of breeding and roosting sites. Major stands of vegetation and other marsh plants are depleted by cattle grazing. Wetlands are reclaimed for agriculture and annual bush burning lead to loss of habitats for the birds. Forests along the shores of the lake have been cut down and the resident fauna killed.

Hunting

Many mammals and birds are hunted for food and as trophies. Elephants, hippos and sitatunga that previously roamed the basin have been almost eliminated. Hippos have been hunted to extinction in many areas, such as in Kagera and Mwanza regions. Destruction of water birds ranges from of trapping adults to collection of eggs and fledglings for food. Trapping of adults is done with baited hooks, and most target species such as ibises, cormorants, and pelicans and this practice is widespread among fishermen.

Although live bird trade is legally allowed, those who are involved in this business tend to catch target species in large numbers without considering breeding succession and recruitment of such species. Crowned cranes and the Shoebill (or Whale-headed stork) have been hunted for trade to almost total extinction.

Human settlement

The increase in human population within the LVB has meant that man acquires more and more land for himself at the expense of other fauna. Crops that he grows are occasionally destroyed by the animals he displaced and there is need to eliminate these pests. Fringing wetlands in Yala, Mara and Mwanza regions are used as roosting sites for bird pest species such as the weaverbirds and Red-billed quelea (*Quelea quelea*). Populations of this locally migratory species reach peaks during May-July period, the time when most cereal crops ripen. In order to reduce damage to crops, the Ministry of Agriculture carries routine aerial spray of avicides so as to bring down the population levels of pest birds. Such spraying is done during dusk when many species have returned for roosting. This results in mass killing of target and non-target species. At Rubana wetland, fishermen usually find mass kills of fish after spraying.

3.9.5. Gaps in information and data in non-fish aquatic vertebrates

Other than birds and large mammals which have had some degree of scientific investigation in the region, the status of other groups of non-fish vertebrates is not well understood. The common feature of these less studied vertebrates is that they show little mobility within the basin. Amphibians in particular have very little ability to move long distances away from their resident habitats. Leaf frogs for example have been unable to travel over large distances until recently with the help of mobile water hyacinth mats. Small mammals such as rats, mice and lizards tend to stick in families within restricted distances. Studies so far undertaken have been restricted in coverage. Only selected sections of the basin have been investigated thus leaving out the bulk of the areas and thus yielding a sketchy understanding of the dynamics of these organisms. A more focused and detailed survey targeting each of these least understood groups is needed to provide a complete documentation of these vertebrates in the Basin.

3.9.6. Conclusion and recommendations to reduce the threats and fill gaps

Amphibians, reptiles, birds and mammals in the LVB threatened by the demands due to increases in human population especially land for settlement. As a result the fauna has been displaced from its natural habitats and thus putting at risk.

The habitat of amphibians has been modified by man’s activities, exposing them to dangers associated with the new environment so created. While some effort has been initiated, a more detailed study is necessary in the whole region to document the status of this group of vertebrates.

Most water associated reptiles depend to some extent on fish for food. The general decline in stocks of fish in the water bodies within the basin is taking its toll on these animals. Crocodiles whose diet consists of fish and birds have been starved to the extent that they have resorted to killing humans. In the process, humans are killing them to counter this threat. Their numbers are so low that had not been for the intervention of institutions dealing with protection of wildlife, they would by now be eliminated.

The LVB was once habitat to many large mammals. Elephants, hippos and buffaloes roamed the shores of the lake. These animals are now restricted to game parks such as Serengeti in Tanzania and Mburo in Uganda. These areas of game reserves are in danger of invasion for agriculture and pasture. With time populations of mammals in the basin are bound to decline.

Survival of aquatic birds relies in conservation of feeding, breeding, roosting, loafing, and over-wintering sites. Water birds derive their diet from lakes and associated wetlands and many species use these areas for nesting and roosting. Measures for management of birds therefore need to also focus on wetland ecosystems. The establishment of Ramsar sites in the basing goes a long way in protection of the waterfowl biodiversity.

Key facts about non-fish vertebrates in the LVB

i) The Lake Victoria basin harbours a wide range of aquatic non-fish vertebrates: the most common groups are: amphibians, reptiles, and birds. However mammals such as hippos, sitatunga, elephant, buffalo, and wildebeest though much less common than in the past still depend on the water resources in the basin.
ii) In terms of numbers of species, birds are the most representative non-fish vertebrates in the LVB.
iii) The LVB is a major route for migratory birds between the northern and southern hemispheres.

3.10. GENETIC DIVERSITY

3.10.1. Introduction

Genetic diversity is genetic intraspecific variability, biological diversity. On the gene level variability represents the existence of variants (alleles) of individual genes resulting from alterations of the DNA sequence. The alleles of a particular gene may occur in different groups of interbreeding individuals (populations). Genetic variation of a particular species is therefore distributed both within populations and between populations (differences in occurrence and frequency between populations. However, much of this variation is normally threatened and often in danger of extinction because most focus in conservation of natural resources is put at saving species or habitats than varieties or strains of a species.

A genetically sustainable fishery is a fishery that does not result in unacceptable loss of genetic diversity and/or change of genetic composition of distinct populations or communities. However, what is not clear is the level of loss/change that may be regarded acceptable. A significant loss of genetic diversity is detrimental to populations and affects their future sustainability. In the short-term, reduced genetic diversity can contribute to inbreeding, depression, lowering population fitness. In the long-term, it reduces the populations' resilience because the potential responses by gene pool to stress is restricted.

Several exploited fishes e.g. Nile perch, Nile tilapia and *Rastrineobola argentea* are divided into genetically distinct local populations, with limited migration among population units. These are called stocks. At the population-level, genetic diversity indicators have the potential to provide meaningful information about the condition and long-term vitality of aquatic organisms. The geographic distribution range of local populations varies substantially and depends on a number of factors such as ecosystem features and ecological interactions. Natural selection may favour particular alleles in particular geographic regions, resulting in local adaptation.

3.10.2. Status of Aquatic Genetic diversity

Tilapiines

Most genetic studies in the LVB have focused on species of economic, ecological and scientific importance. After the initial reduction in population size due to over fishing, the recovery of the native species was thought to have been hindered by competition and hybridization with the introduced, non indigenous congeners and predation by Nile perch. Currently the ruminant populations of *O. esculentus* are only found in satellite lakes, while those of *O. variabilis* occur as both disjunct populations within Lake Victoria and as isolated populations in a few Kyoga satellite lakes. The stenotypic ecological character and hybridization with the more versatile *O. niloticus*, has made the continued existence in the wild of the two native species precarious and there is a need for urgent direct intervention. Recent studies indicate that the both the introduced species and non-indigenous species are highly subdivided into distinct evolutionary groups in the different water bodies in the basin. Genetic analysis of *O. variabilis* and *O. esculentus* that coexisted with congeners indicated that hybridization had occurred and that populations were phyletically closer to the congeners than to putatively pure populations of conspecifics. With the known ecological marginalisation and the evidence for hybridization, *O. variabilis* remains the more vulnerable of the two native species.

The *O. esculentus* populations that coexisted with *O. niloticus* as most dominant e.g. Lakes Kachera and Mburo in Uganda were found to be genetically closer to *O. niloticus*. The micro-satellite data showed Nile tilapia to be the least differentiated among populations, while *O. esculentus* exhibited the highest level of population subdivision. All the phylogenetic trees generated indicated *O. esculentus* as being closer to *O. leucostictus* and *O. variabilis*, than to *O. niloticus*. *O. esculentus* might have adopted the flexibility as a strategy for surviving the competition and the threat to extinction.

These data together with earlier studies indicate that continued existence of the native forms has been compromised both ecologically and genetically through reduced relative abundances, interspecies competition and hybridization with the introduced non indigenous congeners.

Labeo victorianus **(Ningu)**

Labeo victorianus (Ningu) is an endemic cyprinid fish originally dominated the riverine fishery in the basin. The fish was overfished prior to the 1960s and later its populations declined further due to the combined effects of the introduction of competing non-indigenous fishes in the two basins, degradation of its habitat and the use of wrong fishing gears along river mouths during upstream migration. Currently, *L. victorianus* is only extant in isolated and/or disjunct small populations of no commercial value around rivers (e.g. Sio, Kagera, Nyando etc.) adjoining Lake Victoria. Genetic analysis indicated that individuals of *L. victorianus* were subdivided into genetic groups associated with stream or locality. Despite the local differentiation, migration between populations was evident from the low proportion of unique alleles. Overall, variability in *L. victorianus* populations could further be by the high polymorphosim.

Comparison of remnant populations of *L. victorianus* and populations with samples from two allopatric congeners, *Labeo horie* and *Labeo coubie* from Lake Albert based on randomly amplified polymorphic DNA (RAPD) to identify molecular markers indicated marked differences between populations by locality. A comparison of genetic variability between the three species showed that *L. victorianus* retains slightly more variation per population than is seen in the other forms. For each of the three species of *Labeo*, gene diversity within populations measured by RAPDs was relatively low. *Labeo* populations had lower levels of genetic variation than those observed in samples from Lake Albert of the cyprinid *Barbus bynii*, and the characid species, *Alestes baremose*, or than had been previously observed in several tilapiine cichlids from the Lake Victoria basin. However, a related study based on allozyme electrophoresis on different populations within the basin reported weak genetic differentiation amongst *L. victorianus* populations.

Haplochromines

Initial studies on haplochromine species were mainly on the species radiation, phylogenetics and loss of species. Recent studies spearheaded by scientists at Ohio State University and Boston University focused broadly on detailed studies of individual key haplochromine species Other recent studies have suggested that the Lake Victoria endemic haplochromines were derived from a Congolese/Nilotic genus *Thoracochromis* that is also highly diverse both morphologically and ecologically, and was in agreement with the existing morphological and ecological diversity. The study explains the unusually rapid speciation, in that it accounts for source of the numerous mutations that would otherwise have not occurred with the lifetime of the existing young Lake Victoria. In other words, if the morphological and ecological diversity did not exist in the ancestors of the existing flock, it would be very unlikely that the diversity we observe now resulted from recent mutations. For so many mutations to accumulate, it would need a much longer time than the 14,600 years of the lake existence.

Nile perch (*Lates niloticus*)

Genetic analysis of *Lates niloticus* (Nile perch) has focused on identifying which of the two populations from lakes Albert and Turkana became established in Lake Victoria and establishing possible genetic drift. Besides, genetic drift caused by the relatively small founder population (approximately 400), the initially slow population increase followed by a period of explosive population growth and selection pressures in the new environment may have resulted in substantial genetic changes. Results from allozymes electrophoresis suggested strongly that the survivors of the introduced *Lates* were from Lake Albert. None of the other species appeared to have become established in Lake Victoria and in other lakes where *Lates* was introduced e.g. Kyoga and Nabugabo. The same studies further indicated loss of genetic variability both during and after introduction. In addition, introduced Nile perch from lakes Kyoga and Nabugabo were genetically differentiated, suggesting genetic drift following each of the introductions. The reduction in genetic variability and subsequent genetic differentiation may affect the adaptability and thus the persistence of the introduced population in the rapidly changing environment of Lake Victoria, and may therefore have implications for the management of the fishery as well as for the conservation of endangered species.

3.10.3. Threats to genetic diversity

The main threats to genetic resources overexploitation, habitat degradation, pollution and climate change. Fishing may reduce population sizes to levels that favour inbreeding and loss of genetic diversity through the process of genetic drift. Fishing certain sizes or age classes may alter the genetic composition of fish population through selection. Fishing also affects gene flow between local populations and eventually genetic population structure e.g. the initial reduction of native tilapiines (*Oreochromis esculentus* and *O. variabilis*) in the main Lake Victoria. The original major commercial fisheries species in the Lake Victoria basin rivers *Labeo victorianus* and *Barbus altianalis*, are reduced to non-commercial levels and are rare in most rivers in the basin, and are currently considered endangered.

Fish species introductions may result in hybridisation between introduced and native species, which results into alterations of genetic composition. Introductions may change the demographic characteristics of population which results in increased concurrencies of inbreeding and loss of genetic diversity. The reduction in populations of native tilapiines in Lake Victoria after established of the introduced species for example was through predation by the Nile perch and hybridization of introduced species with the native species. The Nile tilapia (*O. niloticus*) remains the basis of the tilapia fishery in the LVB, an introduced non-indigenous species which together with the Nile perch and a small native minnow, *R. argentea*, form the basis of the current fishery in Lake Victoria.

3.10.3. Key endangered species

Endangered species at genetic level are associated with a phenomenon called Genetic swamping i.e. a situation where a population of a species declines or disappears as a result of hybridization with other species. One tilapia species *Oreochromis spirulus nigra* in the LVB is already categorised as endangered because it has been lost through genetic swamping. *O. spirulus nigra* is currently absent in its native range of Lake Naivasha and from three other lakes in the LVB such as Kachera and Mburo where it was introduced followed by *O. niloticus* and *O. leucostictus*. The decline in populations of *O. esculentus* in the basin has been attributed to hybridization with *O. niloticus* w.

3.10.4. Gaps in genetic diversity data

Data on genetic diversity is lacking for the majority of aquatic biota in the LVB. Even the available baseline data on selected species can not be readily located and accessed by the end users.

3.10.5. Conclusion and recommendations

Currently, so little is known about the genetics of fish species and stocks in the LVB that may become important to aquaculture, industry and conservation in the future. Therefore, it is important to conserve not only currently economically valuable aquatic genetic resources, but also those that may be useful in future. For *L. victorianus*, natal stream fidelity seemed to play important role leading to genetic differences between local populations and thus population isolation.

An expert scientific review of the available information on genetic diversity of aquatic resources in the Lake Victoria basin is long overdue and should aim at capturing the gaps.

Supportive breeding of native species and highly selective fishing pressure on the introduced species *O. niloticus*, however the latter is difficult as a there is no gear known to discriminate tilapiine species. Boosting the relative abundance of native species *O. esculentus* and *O. variabilis* will protect them from genetic swamping. Higher numbers ultimately translate into continued maintenance of genetic variability by reducing loss due to chance or genetic drift associated with reduction e.g. In Lake Kanyaboli *O. esculentus* has maintained its dominance over its congeners because of its high relative density.
A distributed fish tissue sample and data bank hosted by a selected institution in the LVB should be created to ensure that existing tissue collections are kept beyond the life of the projects.

There is need to evaluate the genetic consequences of selective fishing gear and possibilities of using gear/practises that minimize genetic impacts

Information sharing of genetic diversity information between the different experts in stock assessments and population studies, the transparency of decision making at management level and increased collaboration between research and management institutions and resource users.

Aquaculture and stocking natural populations should be evaluated from a conservation genetic perspective prior to being conducted.

Given recent severe decline in population size of *L. victorianus*, and the evidence for isolation and differentiation between populations, more comprehensive studies involving use of RAPDs to evaluate the genetic constitution of the species population is imperative so that a plan is developed to conserve genetic resources of the species to ensure its long-term survival.

3.10.6. Key facts on genetic diversity

Generally, management of living aquatic resources and in particular in the Lake Victoria basin should be based on genetic population rather than the geography or tradition.

Currently, there is little information on genetic diversity on biota in the basin but even the little available is not utilized fully in making management decisions.

Incorporation of genetic population structure into management practices is crucial to prevent unnoticed erosion of genetic variability and loosing capability of species to adapt to environmental change e.g. global warming.

The current harvesting methods used in the lake basin are generally selective e.g. Regulation based on mesh size and minimum size has selective effects on the fish, which may in turn result in unwanted genetic effects.

Stock enhancement of wild stocks based on stocking or restocking poses a great threat to genetic diversity and should be guided by criteria for biological sustainability.

3.11. GUIDELINES ON NETWORKING OF INSTITUTIONS AND EXPERTS FOR DATA SHARING AND UPDATES

3.11.1. Introduction

One of the constraints to conservation of aquatic biodiversity and sustainable use of its components is lack of a central database to guide management decisions. This is partly caused by the way the limited data available is managed by the institutions and experts, the limited infrastructure and human resources capacity in the institutions. The available data is recorded and stored in different a format which complicates creation of databases. There is also lack of clear policies for sharing information and data between institutions and experts.

3.11.2. Institutions responsible for collecting biodiversity data and their ownership

There are national/government, academic, regional and international institutions and NGOs and parastatals collecting biodiversity data in the LVB. Key among these include: The government/national fisheries research institutions such as NaFIRRI, KMFRI, TAFIRI, and the departments/divisions responsible for management of fisheries, water, wetland and wildlife; Universities such as Makerere, Dar es Salaam, Sokoine, Nairobi, Moi, Kenyatta, Maseno, Masinde Muliro; Government parastatals such as the NEMAs, the Wildlife Authorities, and National museums, and NGOs such as Osienala, LBDA, UFFCA, LANESA, Fish processors and exporters associations; and Regional organizations such as LVFO and International organisations like IUCN and WWF.

3.11.3. The aquatic biodiversity data collected by the institutions

The above institutions have data on: Aquatic ecosystems (lakes, rivers, wetlands, dams, streams, ponds); Aquatic organisms/species (macrophytes, algae, invertebrates, fishes, amphibians, reptiles, birds, and mammals); and to a limited extent genetics. There is however hardly any data on micro-organisms especially bacteria, fungi and viruses. Most of the data collected is also confined to commercially important fish species on the main Lake. There is need to improve data collection on other aquatic systems and organisms.

The data collected on ecosystems include: Coverage (area or length); human and environmental drivers of change in ecosystems and organisms/species. Data collected on wetlands includes: List of species, their distribution and abundance; Plants of economic values; Soils of economic value (sand, clay etc); and Plants of medicinal value.

The data collected on organismal/species diversity includes: Composition or inventories of taxonomic groups their abundance, distribution, population structure, the changes in population parameters in time and space, human and environmental factors affecting distribution and abundance, and socio-economics data (fish marketing, fish prices, fish exports quantities and values, consumption etc). The data collected on fishes includes: Fish stock assessment (abundance and distributions); Biology and ecology especially of commercially important fishes; Catch assessment data; and Fishing effort data (number of boats, fishermen, nets). Information on aquatic macrophytes includes: Species inventories, their abundance and distribution; Invasive species such as water hyacinth; and medicinal plants.

Genetic diversity data is available for only a few commercially important fish species. This includes: The population structure, variability and hybridisation of some fish species especially the Tilapiines (*O. niloticus, O. esculentus, O.variabilis*), some haplochromines and *Labeo victorianus.*

3.11.4. The experts responsible for collecting biodiversity information and data

There are experts at research, management and academic institutions collecting information on the different categories of biodiversity. Some of the biodiversity data collected remains with the experts and there are no databanks at most of the institutions. It is therefore important that lead experts are identified in the different areas of biodiversity and if possible, constituted into specialist working groups.

3.11.5. Forms in which the data is kept

The data at the institutions is kept in different forms including: Field data forms and notebooks; Spreadsheets mainly excel; and in databases. There are no standard formats for recording data in specific categories of biodiversity. It is only in fisheries that Standard Operating Procedures (SOPs) have been developed. But even here these formats are not specific for biodiversity needs. Much of the information on biodiversity also consists only of lists of organisms and there is no indication of the values, threats and trends in key parameters to guide development of conservation and management plans. It is therefore necessary to standardise formats for collecting specific biodiversity data and to ensure that the data collected is adequately complete to facilitate decision making. Some of the regional institutions like LVFO have initiated a process of preparing SOPs and setting up fisheries database linking the fisheries research and fisheries management institutions with the LVFO Secretariat. There is need to identify and link institutions which collect similar data to facilitate data sharing and harmonisation of formats as is the case with the LVFO to avoid duplication of efforts and collection of information in varied formats.

3.11.6. Database management capacity

Many of the institutions still lack relevant equipment, software, hardware, LANs, WANs and reliable internet connections. Database equipment are delicate and require effective maintenance and un-interrupted power supply which is lacking in most institutions. There is need to invest in appropriate infrastructure for data storage and exchange and to have reliable supply of power for the equipment. Most of the institutions do not also have competent human resources capacity for data management and there is need to sensitise institutions on the need to have competent database managers. There is also need to train scientists in relevant aspects of data management.

3.11.7. Policies on ownership, accessing and sharing data

One of the major challenges on data management relates to ownership, access and sharing of data. There is no clear data ownership policy in most of the institutions to the extent that some scientists hold on to data even when they are employees of an institution and collection of the data has been funded by the institution as part of their employment. There is also no policy requiring scientists to deposit the data they collect with the institution and regulating release of data by individual scientists. There is need for a clear policy right from the level of the scientist to the institution. Such a policy has to provide clear guidelines including avoiding breaching of intellectual property rights and scientific ethics.

3.11.8. Major gaps

Most of the aquatic biodiversity information available is for the main Lake Victoria. The rivers and satellite lakes have been surveyed very few times or none at all. The available data is also on higher organisms especially fish and there is limited data on lower taxa and virtually no data on bacteria, fungi and viruses. Also, the information on the fishes has tended to cover commercially important species with limited information on non commercial species. There is limited taxonomic expertise in the region. Most of the available data is incomplete and is in different formats. There is inadequate database infrastructure and human resources capacity. These gaps need to be addressed. There are no clear policies on data sharing and these need to be developed.

3.11.9. Conclusion and Recommendations

There are institutions collecting and holding biodiversity and related information in the LVB. These include research and management institutions responsible for research and management in fisheries, water, wetlands, and wildlife; Academic Institutions; Regional or International Institutions; Parastatals and NGOs. These institutions operate primarily at National level and secondarily at regional levels. It is proposed that the networking of the institutions in primarily done at national levels to create national biodiversity databanks. Individual national institutions could also network to create database in specific disciplines as is the case for fisheries institutions under LVFO. The national biodiversity databanks should then be networked regionally to create the regional biodiversity databank. The experts working on specific areas of biodiversity could also be constituted into specialist working groups at national and regional levels as illustrated below. There is also need to improve human resources and infrastructure capacity for data management, to have clear policies on data sharing and to improve data collection on other aquatic systems beyond the main Lake Victoria.

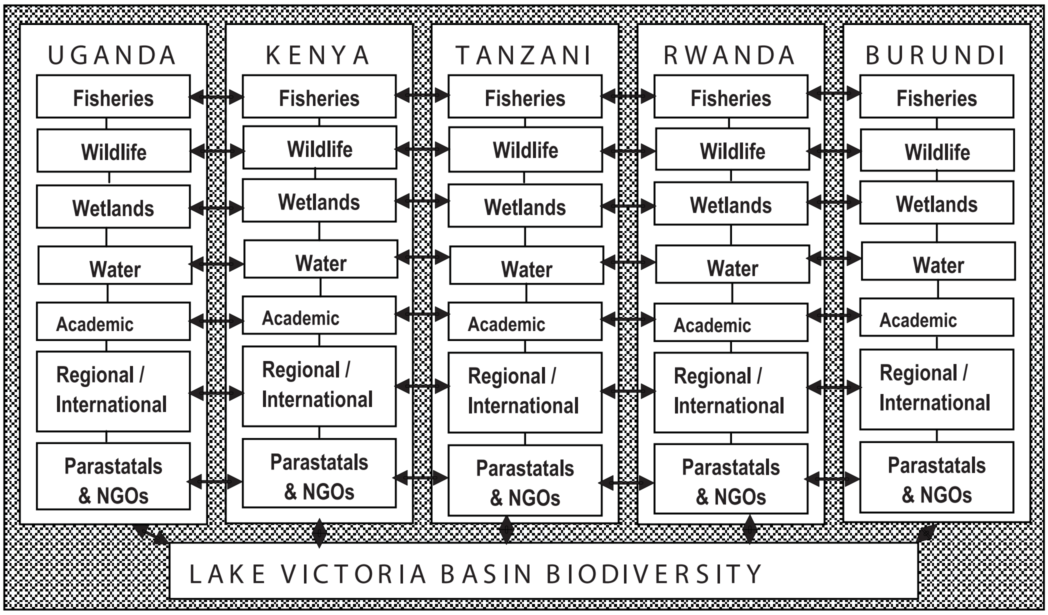

Figure 3.11.1. A diagrammatic illustration of the proposed network of institution of the Lake Victoria Basin for data sharing and update

3.12. POLICY AND LEGAL FRAMEWORKS FOR CONSERVATION OF AQUATIC BIODIVERSITY IN THE LAKE VICTORIA BASIN

3.12.1. Introduction

Efficient and effective management of any resource requires enabling, policies, laws, regulations and effective institutional mechanisms for enforcing the policies and the legal instruments.

Some of the constraints to conservation and sustainable use of aquatic biodiversity are due to inadequate and uncoordinated policies and regulations; Ineffective and uncoordinated institutions that implement the policies and enforce the laws, Conflicting interests in institutions, limited commitment, compromise and sometimes corruption among law enforcers; and limited participation and commitments of the beneficiary communities to sustainable management of the resources. Generally, there are international, regional and national legal instruments that can be applied for management of aquatic biodiversity in the LVB although some of them may need improvement.

3.12.2. General International Legal Instruments

The international declarations include: The Declaration on Environment and Development made at Stockholm in 1972 followed by The Declaration on Environment and Development - the Earth Summit in 1992, The Millennium Declaration and The Johannesburg Declaration on Sustainable Development - the Earth Summit 2002. The Stockholm Declaration commits the nations of the world to sustainable development and provides the basic principles for managing the environment and natural resources. These declarations were consolidated in the Declaration on Environment and Development at the Earth Summit Rio de Janeiro, June 1992 and in the Declaration on Sustainable Development in Johannesburg in 2002. The declarations provide fundamental principles, and programs of action for achieving sustainable development. The Millennium Declaration (MD) specifically sets the international development goals for the 21st century with timelines and commits the international community to assist developing countries financially and technologically to achieve the development goals. These international declarations have generally formed a basis for preparation of development agenda in many developing countries including the EAC although implementation still remains a challenge.

The above international declarations have specific plans of action such as: Agenda 21; The Millennium Development Goals (MDGs); and the Johannesburg Plan of Implementation (JPOI). Agenda 21 sets the international development agenda for the 21st century. The Millennium Development Goals (MDGs) sets the international development goals to be achieved in the 21st century with timelines. The JPOI provides a plan for sustainable development and links with earlier declarations and a number of other international, conventions, protocols and agreements. The plan provides a comprehensive list of actions which if customised and implemented would contribute to sustainable development. Unfortunately, there is limited appreciation of the values of sustainable development especially among the poorer developing countries and many developing countries such as those of the EAC face a challenge of achieving the set goals due to financial and operational constraints. There is therefore need for sensitisation on the concept of sustainable development and for developed countries to assist developing countries in meeting the MDGs.

3.12.3. International Protocols and Conventions

Associated with the above international declarations and plans are a number of international conventions, protocols, and agreements to address specific threats to biodiversity loss such as: The Framework Convention on Climate Change; The Kyoto Protocol; The Vienna Protocol for Protection of the Ozone layer; The Montreal Protocol on ozone layer; and The Convention to Combat Desertification. The Framework Convention on Climate Change aims at regulating and stabilizing concentration of greenhouse gases at levels that do not change the climate. The Kyoto Protocol sets the goals and rules to reduce emission of greenhouse gases. The Vienna Protocol for Protection of the Ozone layer outlines the responsibilities of states to protect human and environmental health against adverse effects of ozone depletion. The Montreal Protocol sets the program for phasing out production, use and consumption of compounds that deplete the ozone layer. Convention to Combat Desertification calls for cooperation in combating drought and desertification and its consequences. Most of these protocols and conventions need international and regional intervention if they have to be affective because their causes and effects go beyond national jurisdictions. There is therefore need for international cooperation in implementing such legal instruments.

3.12.4. Instruments and Plans to Control Water Quantity and Quality

Water quantity and quality is central to conservation and sustainable use of aquatic biodiversity. There are some international policies and strategies that guide management of water resources such as UN-Water and Water Policy and Strategy of UNEP. The UN-Water supports member states in achieving water and sanitation goals, targets as set out in the MGDs and the JPOI. The Water Policy and Strategy of UNEP contribute to environmental sustainability in the management of water resources, through integrated ecosystem approaches. Integrated river basin and watershed management approaches are provided for in the JPOI. There are, however, divergent interests on water use depending on the needs and priorities of individual states and this posses challenges regarding sustainable water use. For instance, there have been concerns regarding release of water for hydropower generation from Lake Victoria and the extent to which the countries around the lake can use the water for irrigation. This is believed to have contributed to changes in the quantity of water in the lake. There is therefore need for clear water access policies especially for shared waters in the LVB.

3.12.5. Legal Instruments to Protect Loss of Species and Their Habitats

The international legal instruments and plans for protection of species and habitats include: The World Heritage Convention; The Convention on Wetlands of International Importance especially as Water Fowl Habitat - The Ramsar Convention; The Convention on Biological Diversity (CBD); The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); The Convention on the Conservation of Migratory Species of Wild Animals; The Code of Conduct for Responsible Fisheries; The International Plan of Action on Illegal, Unregulated and Unreported (IUU) fishing; and the International Plan of Action to regulate fishing capacity.

The World Heritage Convention provides for protection of ecosystems and habitats of global scientific value. African Great Lakes including Lake Victoria are considered as World Heritage sites due to their high biodiversity and scientific value especially due to the large number of endemic fish species. World Heritage sites are contained in a World Heritage Catalogue. There is need to determine World Heritage sites in the LVB for inclusion in the World Heritage Catalogue and to put in place enabling national legislation to manage them.

The Ramsar Convention aims at protection of wetlands to enable them perform their, ecological, economic, cultural, scientific and recreational values especially as habitats of birds and other organisms. Protected wetlands are declared as Ramsar sites. Some of the wetlands within the LVB are protected under this convention. It is important that suitable wetlands in the LVB are identified for protection under the Ramsar convention.

The Convention on Biological Diversity is the key international legal instrument for conservation of biodiversity, sustainable use of its components and fair and equitable sharing of its benefits. Parties to the convention are expected to provide for conservation and sustainable use of biological diversity in their plans, programmes, policies and regulations. Most EAC Partner States have prepared national biodiversity strategies and action plans but most of these have not been implemented. There is need to integrate these plans into appropriate sectoral plans e.g. fisheries, wetlands, wildlife.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) protects trading in endangered species through controlling import and exports. Appendices to the convention have list of species which have reached different levels of danger and are amended depending on the status of the species in the wild. Appendix I contain species threatened with extinction and whose trade is subjected to severe restriction. Appendix II contains threatened species whose trade has to be monitored. Appendix III contains species which are not necessarily threatened but require protection. A limitation in data availability is a major constraint to determining the status of different species. There is need to determined the status of traded wild flora and fauna in the LVB to guide their placement on the CITES lists.

The Convention on the Conservation of Migratory Species of Wild Animals is aimed at protecting wild animals that migrate outside national boundaries. This includes not only birds but also fish and other animals. It provides for protection of species like birds which migrate during winters and fish like *Labeo victorianus* which migrate to breeding grounds and includes protecting feeding, breeding and wintering habitats of the species. It also has Appendices (I & II) which contain lists of some migratory species. Appendix I contains some of the globally endangered migratory species. There is need to identify migratory species in the LVB and their status and to suggest their placement in the Appendices. Some aquatic habitats especially wetlands are known to be Important Bird Areas (IBAs) and should be identified and protected.

The Code of Conduct for Responsible Fisheries provides international guidelines and standards for conservation, management and development of living aquatic resources and their environment. Although this is largely voluntary, it has been used as a basis for fisheries management. There are many international legal instruments associated with this code such as the International Plan of Action on Illegal, Unregulated, and Unreported (IUU) fishing which aims at combating IUU fishing. A regional plan to combat IUU fishing on Lake Victoria and its basin has been prepared but implementation has not been effective and illegalities in the fishery have continued to the detriment of commercially important fisheries. There is need to combat IUU fishing on Lake Victoria.

3.12.6. Regional Legal Instruments for Management of Biodiversity

The EAC Partner States have legal instruments and action plans which can be applied in biodiversity management. These include: The Treaty for the Establishment of the East African Community; The Convention for Establishment of Lake Victoria Fisheries Organization; The Protocol for Sustainable Development of Lake Victoria Basin; The Protocol on Environment and Natural Resources Management; The Regional Plan of Action to prevent, deter and eliminate IUU fishing on Lake Victoria and its basin (RPOA-IUU); and The Regional Plan of Action for Management of Fishing Capacity (RPOA-Capacity) in Lake Victoria.

The EAC Treaty provides, for sustainable utilisation of the natural resources through taking measures that protect the environment. The Convention for Establishment of Lake Victoria Fisheries Organization (LVFO) provides for harmonization of measures for the sustainable development and management of the living resources of Lake Victoria. The Protocol for Sustainable Development of Lake Victoria Basin includes provisions for protection and conservation of the basin and its ecosystem, sustainable development of natural resources including fisheries and prevention of pollution. The Protocol on Environment and Natural Resources Management provides for cooperation in management of the environment and natural resources including water resources, biological diversity, wetland resources, forest resources, wildlife, fisheries, genetic resources. RPOA-IUU provides for management measures to prevent, deter and eliminate IUU fishing, to conserve the fish species, protect the environment in the LVB. RPOA-Capacity aims at control of fishing capacity. The mechanism for allocation of fishing capacity among the Partner States has not been agreed upon. Consequently, fishing capacity has continued to increase and commercial fish stocks have continued to decline. There is need to implement the agreed plan of action.

3.12.7. National Legal Instruments for Protection of Biodiversity

The Partner States have legal instruments, which cover management of aquatic biodiversity. These are mainly included in the national constitutions, policies and legislations of environment, water, wetlands, forests, wildlife, and fisheries. The national constitutions provide for measures to protect and preserve the environment. The other cross-cutting national legal instruments are those for management of the environment and associated environmental impact assessment (EIA) regulations. The environmental regulations provides for conservation and sustainable management of the environment including lakes, rivers, water, wetlands, forests, biodiversity, genetic resources, control of pollution, natural heritage sites, river banks and lake shores, soil, and air quality standards, EIA and audit, and protection of ozone layer. The provisions of environmental regulations are generally good but implementation is challenging. There is need for sensitisation of communities on their value and utility. There is also sometime government interference. EIAs are sometimes perceived politically as hindering development and there is need for change in attitude.
Management of wetland is sometime covered under environment and water legislations. There has, however been continued encroachment on wetlands in the Partner States and these need to be addressed.

The EAC Partner States have national water and related legal instruments such as:
The Water Statute 1995, Uganda; The National Water and Sewerage Corporation Statute, Uganda; The National Policy on Water Resources Management and Development, Kenya; The Water Act cap 372, 2002, Kenya; and The Water Policy 2002, Tanzania. The legal

instruments on water management provide for: planning, use, protection and management of water resources and supply; water permits; waste discharge; effluent discharges; control of water abstraction; water quality monitoring, pollution control; water supply and sewerage treatment and contain water quality standards for different uses. The water quality standards are difficult to adhere to especially in rural areas. There is still poor observance of sanitary standards such as washing cars, clothes, bathing etc and disposal of materials in water bodies and these needs to be observed. There is disposal of largely untreated waste in some towns like Kisumu, Mwanza, Homa Bay, Jinja etc. There is need to reduce discharge of waste into the aquatic ecosystems by the peri-urban areas so as to maintain the health of aquatic ecosystems.

Although forests are not strictly wetlands, they play an important role in stabilization of ground water, protecting water catchments and moderating climate change by absorbing greenhouse gases, and are locus of high biodiversity and habitat for wildlife. Forests such as Mau and Elgon play important roles in water catchments and there is need to identify and manage such forests as part of management of aquatic biodiversity; the function of forests in stabilisation of water catchments and in modulation of local climate resulting in rainfall needs to be emphasised. There is also need for a clear policy on forests that stabilise trans-boundary climate of the LVB such as those of Mabira and Sese Inslands.

There are national legal instruments for fisheries management such as: The National Fisheries Policy, Uganda; The National Fisheries Policy, Tanzania; The Draft National Fisheries Policy, Kenya; The Fish Act cap 197, 1967; The Fisheries Act cap 378, 1991 for the Republic of Kenya; and The Fisheries Act No. 22 of 2003 of the United Republic of Tanzania. The Fisheries Acts are supported by a number of regulations, statutory instruments, and gazette notices.

The fisheries policies and Acts provide for: Control of fishing, optimal and sustainable exploitation, management and development of fisheries. Most of the Acts are not clear in conservation and sustainable use of fish species diversity. The main focus of both the policies and regulations are on commercially exploited fishes. There is need to include aspects of conservation and sustainable use. There is very limited provision for creation of protected areas such as marine parks. There are very few, if any conservation areas in Lake Victoria and there is need to identify and demarcate such areas for purposes of conserving fish stocks and other aquatic organisms. Enforcement of the law has been a challenge as fish stocks have continued to decline. BMUs might assist. There is need to strengthen enforcement of the laws and regulations.

Some organisms that are not covered specifically under sector specific regulations such as the Fisheries Acts are covered under Wildlife regulations by some of the Partner states. These provides for sustainable management of wildlife covering wild plants and animals. They provide for setting up of wildlife conservation and protected areas, their management, protected species, wild life user rights and International trade in wildlife. These regulations can therefore be used for those aquatic organisms not covered by other acts such as the Fish Acts. There is need for a clear linkage between components of wildlife not covered under other sectoral laws such as the one on fisheries and wildlife acts.

3.12.8. Conclusions and Recommendations

There are international legal instruments to manage habitats, species and genes but there is limited appreciation of the values of sustainable development especially among the poor countries. There is therefore need for sensitisation.

Developing countries face challenges of achieving MDGs due to financial and operational constraints and will need assistance from developed countries.

Most of the protocols and conventions need international and regional intervention to be affective because their causes and effects go beyond national jurisdictions. There is need for international cooperation in implementing such legal instruments.

There are divergent national interests on some resources such as water use depending on the national priorities which poses challenges regarding their sustainable use. There is need for consensus in dealing with such resources.

There is need to determine World Heritage sites in the LVB for inclusion in the World Heritage Catalogue and to put in place enabling national legislation to manage them.

Suitable wetlands in the LVB should be identified and protected under the Ramsar Convention. Some wetlands are known to be IBAs and these should be protected.

Most EAC Partner States have prepared national biodiversity strategies and action plans but most of them have not been fully implemented. There is need to integrate these plans into appropriate sectoral plans e.g. fisheries, wetlands, wildlife to hasten their implementation.

There is need to determine the status of traded wild flora and fauna in the LVB to guide their placement on the CITES lists.

There is need to identify migratory species in the LVB and their status to guide their protection.

Partner States should commit themselves to implementation of RPOA-IUU because the fishery has continued to decline despite adoption of this legal instrument.

Fishing capacity has continued to increase and commercial fish stocks to decline despite adoption of RPOA-Capacity and there is need for controlling fishing capacity.

There is still poor observance of sanitary standards such as washing cars, clothes, bathing and disposal of untreated waste in some towns like Kisumu, Mwanza, Homa bay, Jinja and this should be avoided.

There is need for a clear policy on forests that stabilise trans-boundary climate of the LVB such as those of Mabira and Sese Islands.

There are very few marine parks in LVB. There is need to demarcate marine parks so as to conserve fishes and other aquatic organisms.

Enforcement of fisheries laws has been a challenge as fish stocks have continued to decline. All efforts should be made to improve law enforcement including use of BMUs.

There is need for a clear linkage between components of aquatic organisms not covered under sectoral laws such fisheries to other such as wildlife.

Application of the different international, regional and national legal instruments has, generally been weak resulting in continued loss of ecosystems, species and genetic resources. There is need for the Partner States to strengthen enforcement of legal instruments including involving user communities.

4. A SUMMARY OF RECOMMENDATIONS TO REDUCE THE THREATS AND FILL THE GAPS

It was noted that the biggest threat to aquatic biodiversity is the increasing human population and demands it puts on the resources. However, since the human population will inevitably continue to increase, what is required is how to manage the biodiversity resources sustainably to meet the demands of the increasing population so as to fulfil the LVB vision of having *"A prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits".*

Overall, it is recommended that:

i) Communities should be sensitised on the benefits of sustainable use of the resources.
ii) Enforcement of existing legal instruments by involving user communities to develop appropriate ones should be strengthened.
iii) Standard data collection procedures for assessment of components of biodiversity should be developed to facilitate comparability.
iv) Modalities for sharing of information on aquatic biodiversity should be developed and information sharing improved.
v) Indicator taxa which can be used in monitoring the health of ecosystem/organisms should be identified.
vi) The impact of climate change on ecosystems and the diversity of organisms/species should be determined.
vii) Skills in taxonomy of aquatic organisms should be enhanced.

On the values of biodiversity, it is recommended that:

i) The values of components of biodiversity and their contributions to economies at local, national and regional levels should be determined.
ii) Studies should be conducted on utilization and quantities of water from the different aquatic ecosystems.
iii) Patterns of navigation on the lakes and rivers including their volumes and values, and the volumes of traffic for goods and passengers should be monitored.
iv) Production and marketing of the less significant fish from, lakes, rivers and wetlands should be evaluated and monitored.
v) The structure and volumes of tourism and sports on aquatic ecosystems including ornamental fisheries should be determined.
vi) Studies of the cultural uses of lakes, rivers and wetlands by the local communities should be conducted.
vii) The potential and actual exploitation of hydro-electric power from the different rivers within the LVB should be determined.
viii) Utilization of wetland resources for crafts, packaging, construction and other uses should be monitored
ix) Management systems for the utilization of the different biodiversity resources should be determined.
x) Indirect use, option values and intrinsic values of biodiversity should be quantified

On lake ecosystems, it is recommended that:

i) A new Lake Victoria water release policy should be developed to guide release of water from the lake so as to maintain the quantity of water at economic levels.

ii) The water budget of the lakes should be monitored.
iii) The role of ground water in the water budget of lakes levels should be determined.
iv) Activities which increase the concentration of nutrients especially phosphorus, Nitrogen and pollutants into aquatic systems such as bush burning should be regulated.
v) The spread of and changes of anoxia in time and space in Lake Victoria should be monitored.
vi) The level of siltation of lakes should be determined and monitored.
vii) Habitats that are important in conservation of fish species diversity should be identified and marine parks established and gazetted.
viii) Management plans should be prepared for individual satellite lakes.
ix) The potential of individual satellite lakes to produce fish should be determined.
x) Wetlands especially those around satellite lakes should be protected to stabilize water.
xi) Satellite lakes which are important in conservation of endangered species should be identified and protected.

On river ecosystems, it is recommended that:

i) Information and data should be collected on characteristics of rivers, their physical environment and biotic communities.
ii) Catchment activities that degrade riverine habitats should be managed.
iii) The silt load of individual rivers should be determined and monitored.
iv) Over-exploitation of riverine fishes should be avoided especially during the breeding rainy season by protecting fishing at the mouths of rivers when fish migrate upstream to breed.
v) Catchments which stabilize ground water supply to rivers such as forests should be identified and protected.
vi) Regulations that govern conservation of ecosystem, especially river banks should be enforced.
vii) The impact, real or potential, of human activities on riverine ecosystems should be monitored.

On wetland ecosystems, it is recommended that:

i) An inventory of wetlands including extent, location and distribution should be made and their distribution patterns monitored.
ii) The biomass of valuable wetland commodities should be determined.
iii) The uses of different wetlands and their comparative advantages should be determined.
iv) Plans should be prepared for sustainable use of wetland resources putting in mind their comparative advantages (e.g rice growth, filtration, clay sand etc).
v) Wetlands which are important in biodiversity conservation and those with highly threatened taxa and habitats should be protected.
vi) Strategies should be developed for rehabilitation of degraded wetlands.
vii) Suitable wetlands should be identified and designated as Ramsar sites.
viii) Studies should be conducted on habitats and water quality in the wetlands especially as indicators of environmental change.
ix) Traditional management practices of the user communities should be integrated in wetland management programs.

x) The levels of awareness on threats and impact of human activity on wetlands should be assessed and enhanced.
xi) Capacity should be built at community level for proper and wise use of the wetland resources.
xii) Partner States which do no have specific policies, legal and institutional frameworks on wetland management should be encouraged to develop them and these should be harmonized.

On aquatic macrophytes, it is recommended that:

i) An inventory and distribution of aquatic macrophytes should be made sustainable use practices for the macrophytes developed.
ii) The spread of invasive alien macrophytes such as water hyacinth should be monitored and controlled.
iii) Potential use of invasive macrophytes should be made as one of the strategies to control them.
iv) The conservation status of endangered macrophytes should be assessed and action plans formulated to protect them.
v) Species of macrophytes that perform vital functions such as filtering pollutants, contaminants and silt should be identified and plans made to conserve them.
vi) The contribution of macrophytes to the aquatic food web should be determined.

On algae, it is recommended that:

i) Data should be collected on algae from satellite lakes and rivers to augment that on Lake Victoria.
ii) The roles of algae in the aquatic food-web should be determined.
iii) The composition and distribution of algae that produce toxins should be determined to prevent their impact on water users.
iv) The relationship between composition, abundance and trends of algal communities and the nutrient status of lakes and rivers should be monitored.
v) The relationship between physical factors (wind, solar energy, mixing patterns or regimes and temperature) of aquatic systems and algal communities should be determined.
vi) The sources of nutrients notably P and N that control algal blooms and alter algal species diversity should be monitored and controlled.
vii) Nutrient loading in aquatic systems should be controlled to prevent further stimulation of algal growth and deterioration of the aquatic environments.

On aquatic invertebrates, it is recommended that:

i) Data should be collected on invertebrate communities in satellite lakes and rivers.
ii) Information should be collected on the role of invertebrates in the aquatic food-web especially in relation to fish production of individual lakes.
iii) Information should be collected on the relationship between invertebrate communities and environmental health of individual aquatic systems.

On fishes, it is recommended that:

i) Fishing pressure and the use of destructive fishing gears and methods is controlled especially on the main Lake Victoria.

ii) An assessment of the fish stocks in individual satellite lakes should be undertaken and any that may require stock enhancement identified.

iii) Refugia of endangered fish species should be identified both in the main lake and the satellite lakes and rivers and protected.

iv) Suitable areas for setting up marine packs in the LVB should be identified and gazetted.

v) The predatory Nile perch should not allowed to spread to the satellite lakes where it is absent.

On non-fish vertebrates, it is recommended that:

i) More data is collected on amphibian, reptiles, birds and mammals to appreciate their role in the ecosystem and value to man.

ii) Important Bird Areas (IBAs) and sanctuaries within the LVB should be identified to protect birds

iii) Important eco-tourism centres especially for bird watching should be identified and protected.

iv) Certain non-fish vertebrates which should are threatened such as crocodiles and mammals like sitatungas should be protected.

On genetics:
There is very limited information on genetic diversity of aquatic organisms and more studies are needed in this area. It is recommended that genetically similar species should not be mixed to avoid hybridization and genetic swamping.

On institutions, it is recommended that:

i) Infrastructure and human resources capacity of institutions to manage information and databases should be improved.

ii) Clear policies on data ownership and sharing should be developed.

iii) Institutions should be networked at national level to create national biodiversity databanks and linked to create regional databases.

iv) Working groups of scientists collecting data on specific areas of biodiversity should be formed to allow harmonisation of data collection and data sharing.

On policy and legal framework, it is recommended that:

i) Developing countries should improve their implementation of international commitments.

ii) Developing countries should solicit funds from developed countries to meet their international commitments.

iii) Regional and international cooperation should be promoted towards meeting those protocols and conventions that need international and regional intervention to be affective such as climate change.

iv) World Heritage sites should be determined for inclusion in the World Heritage Catalogue and enabling national legislation should be put in place to manage them.

v) Suitable wetlands in the LVB should be identified and protected under the Ramsar Convention and IBAs in the LVB should be identified and protected.

vi) Partner States should operationalise their national biodiversity strategies and action plans by integrating them into sectoral policies to hasten their implementation.

vii) The status of traded wild flora and fauna in the LVB should be documented to guide their placement on the CITES lists.

viii) Migratory species in the LVB, especially birds and fish should be determined and appropriately protected.

ix) Partner States should commit themselves to implementation of RPOA-IUU because the fishery has continued to decline despite adoption of this legal instrument.

x) Fishing capacity has continued to increase and commercial fish stocks to decline despite adoption of RPOA-Capacity and there is need for controlling fishing capacity.

xi) Washing cars, clothes, bathing and disposal of untreated waste especially in town such as Kisumu, Mwanza, Homa bay, Jinja should be monitored and avoided.

xii) A clear policy should be developed on forests that stabilise trans-boundary climate of the LVB such as those of Mabira and Sese Islands.

xiii) There are very few marine parks in LVB. These should be demarcated and gazetted as a matter of priority to conserve fishes and other aquatic organisms.

xiv) Components of aquatic organisms not covered under sectoral laws should be identified and catered for under appropriate sectors such as wildlife.

xv) Application of the different international, regional and national legal instruments has, generally been weak resulting in continued loss of ecosystems, species and genetic resources. Partner States to strengthen enforcement of legal instruments including involving user communities.

xvi) Finally, gathering data is not an end to itself but an incremental process that evolves through organizing of existing data and acquisition of more data. The assignment is therefore to be regarded as part of a continuous process.

5. THE META-DATABASE PROTOTYPE

The meta-database on aquatic biodiversity of the LVB brings together information on aquatic biodiversity to a central location where it can be accessed, processed and used by various stakeholders for conservation of biological diversity, sustainable use of its components, and equitable sharing of the benefits from the genetic resources. Location of data and information on ecosystem, organismal/species, genetic biodiversity and associated social economic values together with the drivers of change at different levels, its condition and how it can be obtained is captured in the meta-database.

The objective of the Meta database is to enable easy access to the data on the aquatic biodiversity in the Lake Victoria basin so as to improve planning and decision making. The meta-database is based on internationally recognized standards of FGDC, CSDGM, and ANZLIC. The meta-database provides the structure and format of the data/information, together with conditions and policies for accessing the information. It has formats of table elements that have been used in the design.

The meta-database has a meta-database collector component which is used for collection, maintenance, import and export of data; and the meta-database administrator component which is used for the administration, management and maintenance of the database. The web technology has been used as an interface to interact with the meta-database collector at the backend, which was developed with MySQL.

The website interface is made of a welcome message on the homepage (Figure 1) with buttons that lead you to the meta-database, ecosystem diversity, organismal/species diversity, genetic diversity, institutions, biodiversity experts, policy and regulations, social economics, bibliography, and log-in.

Figure 5.1: Homepage

5.1 Meta-database

The page provides metadata on the structure of the various datasets that are contained in the meta-database. Information on full and short name, keywords, short description, contact references, data distribution policy, status, and the format of the dataset elements is provided. The output is illustrated in Figure 2.

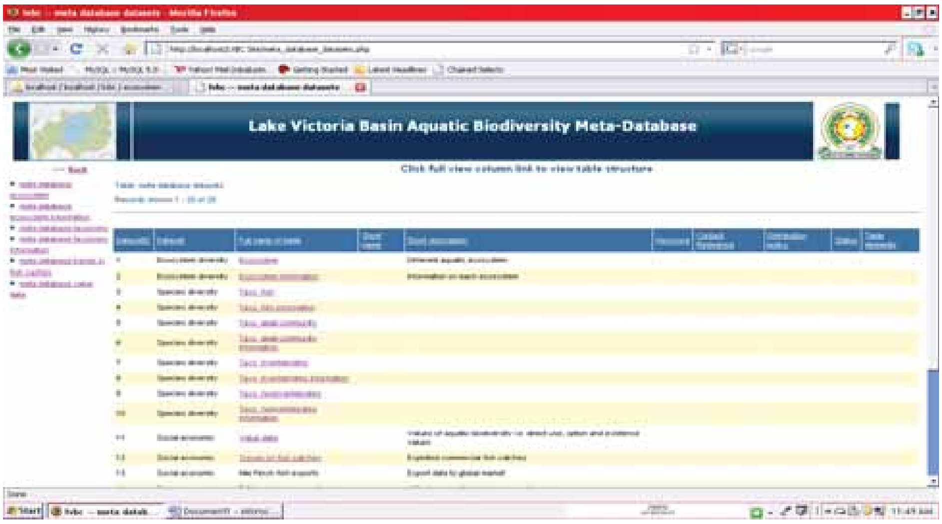

Figure 5.2: Meta-database

5.2 Ecosystem diversity

The page provides information of the 3 ecosystem categories i.e. Lake, River and Wetland, and the related data/information on values, threats, trends, status, and any additional information on each ecosystem. Some of the information has links to other sources. The output is illustrated in Figure 3.

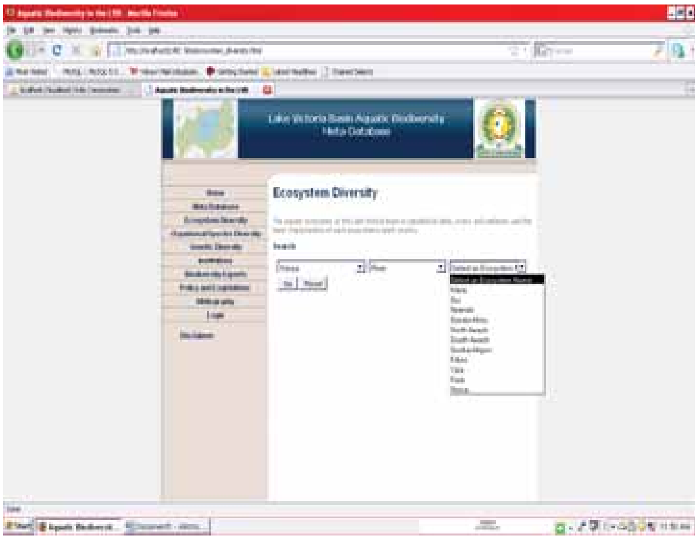

Figure 5.3: Ecosystem Diversity

5.3 **Organismal/Species diversity**

The page provides information on species in the five major sub-sectors i.e. algal community; aquatic invertebrates; haplochromines; non-haplochromines; non-fish vertebrates; and aquatic macrophytes plants in each of the three ecosystems of lake, river and wetland. The page allows to display specific taxonomic data/information of interest up to the species level. Information on trends, values, threats has links to other sources where it can be manipulated by the users. See Figure 4.

Figure 5.4: Species Diversity

5.4 Genetic diversity

This page presents information on genomes and genes of species of commercial, agricultural, medicinal and scientific values.

5.5 Institutions

The page provides detailed information on the various Partner States that are involved in the collection, management and dissemination of data/information on aquatic biodiversity in the Lake Victoria Basin. Details about the institutions are provided together with information on ownership, mandate, format and categories of data under custody, and the data access policy. The output is illustrated in Figure 5.

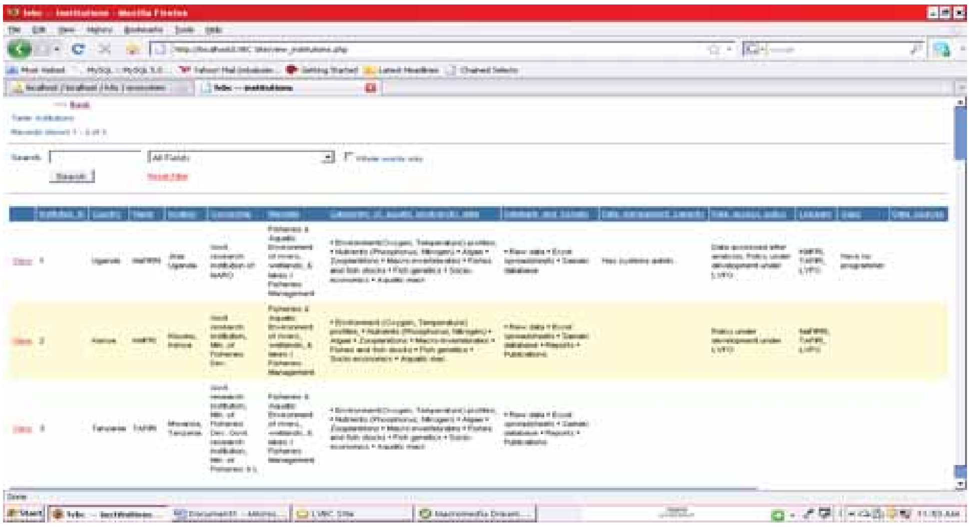

Figure 5.5: Institutions

5.6 Biodiversity experts

The page provides detailed information on the various biodiversity experts that are custodians of data/information in various institutions, and are involved in the enrichment of the meta-database. These experts have the privilege of creating, editing and deleting data in the meta-database. The output is illustrated in Figure 6.

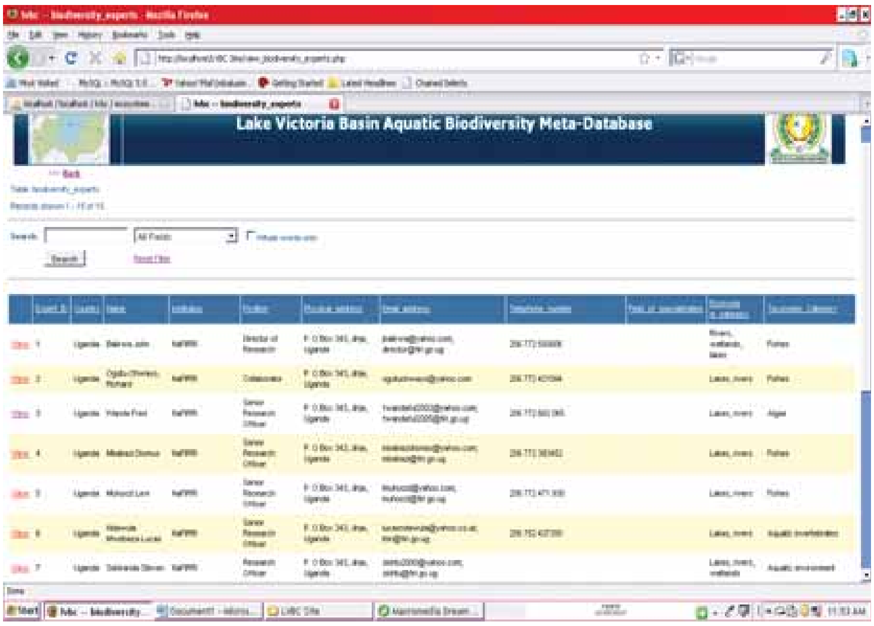

Figure 5.6: Biodiversity Experts

5.7 Policy and regulations

The page provides details of different treaties, conventions, agreements, codes, policies and regulations that have been developed for the efficient and effective management of the aquatic biodiversity in the Lake Victoria Basin. The output is illustrated in Figure 7.

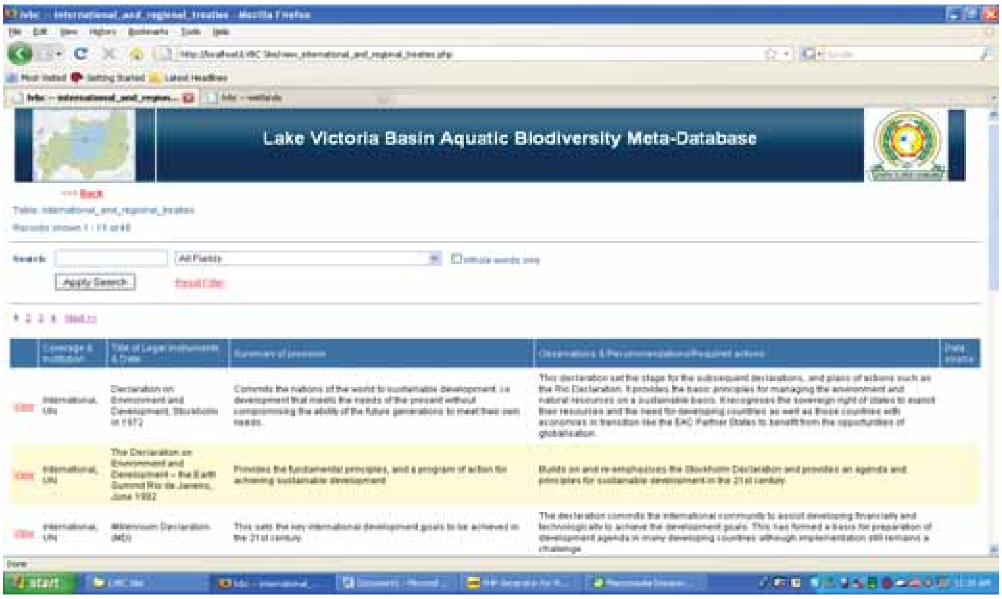

Figure 5.7: Policy and Regulations

5.8 Social Economics

The page presents information on different social economic aspects of the different ecosystems, species, and genomes. See Figure 8.

Figure 5.8: Social Economics

5.9 Bibliography

The page provides information on bibliographic data that has been used in the content and development of the meta-database. Details about the publications and their location are provided.

5.10 Login

The login page requires a username and password. It allows the administrator to administer and manage the meta-database. The biodiversity experts/metadata coordinators are to be given privileges of creating, editing and deleting data on specific pages of their expertise by the meta-database administrator; and they will use this page to login.

Everyone will be able to browse data/information in the public domain, while for the non-public data/information, read only privileges will be provided by the administrator in consultation with the biodiversity expert of the specific data of interest or the institution responsible for the data. Each institution has its own policy on data access, and these policies will guide the administrator in the provision of data usage privileges. See Figure 9.

Figure 5.9: Login

5.11. Conclusion

The developed meta-database is a prototype, such that further improvements will be necessary as more users access the system to cater for their demands. The system will have to be hosted in an institution that has an infrastructure that consist of a main and backup server computer together with an Internet connection of good bandwidth to support the high demands of data. In addition, the institution must have well qualified manpower to administer and manage the meta-database.

It is not recommended for Lake Victoria Basin Commission to acquire the infrastructure that is required to host the meta-database, due to the intricacies involved in administering and managing it successfully. The LVBC should identify host providers (i.e. firms) who have a permanent infrastructure with well qualified manpower, and a track record of providing similar services. Institutions such as Uganda Telecom Ltd in Uganda, Africa Online in Kenya and many others can be contracted to offer the services efficiently and effectively.

As for populating the data, a memorandum of understanding (MoU) must be made between the client and the biodiversity experts or institutions to continue providing the data. The data can be entered directly into the database by the experts. Where it is not possible due to lack of sufficient training, the experts will provide the data in a spreadsheet format to the meta-data coordinator at LVBC who will export it to the meta-database.

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ANNEX II. TERMS OF REFERENCE

Introduction

Lake Victoria Basin Commission (LVBC) is a specialized institution of the EAC that is responsible for coordinating the sustainable development agenda of the Lake Victoria Basin. The establishment of the Commission was provided for under Article 114 of the Treaty for Establishment of the East African Community (1999) and specifically under Article 33 of the Protocol for Sustainable Development of Lake Victoria Basin.

The LVBC has received funds from the Lake Victoria Basin Partnership Fund; a fund established a Partnership Agreement between the East African Community and Governments of Sweden, France and Norway, the World Bank and the East African Development Bank. A portion of this fund has been set aside to facilitate studies Biodiversity within Lake Victoria Basin. The main purpose of carrying out these studies on biodiversity in the Lake Victoria Basin is to bring together biodiversity information to a more centralized access point and facilitate the processing of existing and new biodiversity information into a format where it is readily available to the users, managers, researchers and policy makers.

The overall objective of these studies is therefore to collect, archive and transcribe existing and new biodiversity datasets for Lake Victoria that will not only cover the fisheries but other fauna and flora, process the data and develop procedures for constructing a comprehensive database.

Background to the Study

Since 1920s the Lake Victoria and its Basin has undergone successive dramatic changes. Intensive non-selective fisheries, extreme changes in the drainage basin vegetation, industrialization, agricultural developments, dams and the introduction and invasion of exotic species are among the factors that have led to the destruction of the native and endemic components of the lake. These have been followed by a progressive build-up of physical and chemical changes in Lake Victoria. Other ecological changes indicate a shift in the phytoplankton community towards dominance of blue-greens and an enhancement of algal blooms. In some shallow depths of the lake, anoxic waters have been found suggesting significant increases of oxygen demand in the seasonally formed hypolimnion. This situation has increasingly resulted in the impoverishment of the lake. The lakes ecosystem has also been particularly affected by the introduction of the Nile perch, *Lates niloticus* during 1950s and the water hyacinth, *Eichhornia crassipes* in 1990s, the consequence of which are detrimental to the lake's biodiversity, especially fish; leading to a shift in the fishery from a multi-species to only two major exotic species, *Lates niloticus* and *Oreochromis niloticus* and the endemic species *Rastrineobola argentea* (Ochumba et al., 1994).

There is now concern over widespread loss of biodiversity in Lake Victoria and its Basin (at species, genetic, and habitat levels). Most affected are fisheries, forestry and a range of wild fauna and flora. The high rate of species endemism in Lake Victoria Basin would suggest that biodiversity may be particularly sensitive to threats from industrial pollution, over fishing, invasion of exotic species, and other human activities. The major factors threatening decreased biodiversity of the basin are; Interference with inflowing rivers and water destruction; Illegal fishing and over-fishing; Water level changes; Pollution; Invasive and Introduced species; Climate change; Deforestation through cutting of trees and grass for charcoal and brick burning; Illegal hunting and poaching; open access policy to most natural resources.

The decline in fisheries diversity is probably the most visible representation of the sorry state of biodiversity loss in this fragile ecosystem. The clear threats to some of the economically important fish species (including Haplochromines) heighten concern over general loss of biodiversity. Two major flagship species in Lake Victoria, the Haplochromines and Cichlids (*Labeo*, *Synodontis* etc) are officially classified as threatened. The endemic species fish and bird flocks found in Lake Victoria are today threatened by a variety of human activities.

More than 35 million people who depend on the lake are feeling the consequences of these changes in the biota and the lake environment. In Lake Victoria, as elsewhere, human welfare is intimately linked to concerns for species conservation and ecosystem integrity. At the moment many fauna and flora of Lake Victoria are being intensively exploited to meet escalating needs for human well being but their ecological and conservation status is not clearly known.

The Need for Studies on Biodiversity in Lake Victoria Basin

Despite the massive amount of research carried out in the region, it is almost impossible to obtain information in any aspect of biodiversity in the Lake Victoria Basin. Whenever such information is available, its distribution is either highly restricted or accessibility is very limited. Recent reports indicate signs of population re-emergence of some relict fish species, however the taxonomic details of the said species is wanting. The description of species both flora and fauna is incomplete. For instance surveys undertaken in the Lake already revealed the presence of un-described Anabantid and *Synodontis* fish species. It is thus presumable that there are several species awaiting discovery and description to the rest of the world. In fact there is no complete list and description of the diversity of both flora and fauna in the Basin. Current efforts are uncoordinated as there is no single centralized database on lake's biodiversity to provide information on existing data, ongoing data requisition or even new initiatives.

Specific tasks

The following duties are envisaged by the consultant during the consultancy period:

i) Review of research information on biodiversity in the Lake Victoria basin and identify research gaps
ii) Carry out desktop review on existing biodiversity databases for the Lake Victoria basin
iii) Responsibility of designing data collection sheets for existing databases and all other relevant information on biodiversity in Lake Victoria basin
iv) Visiting the different institutions, organizations and individuals to collect biodiversity information
v) Processing and analyzing the acquired information acquired with a view of designing and harmonizing data existing biodiversity data into a form that can facilitate the development of a comprehensive biodiversity database
vi) Develop a meta-database in line with collected biodiversity information
vii) Make recommendations on the structure of the biodiversity database
viii) Production of a consultancy report

Expected outputs

The main expected outputs for the proposed activities will include:

i) Summary report on the status of biodiversity research and identified gaps
ii) Comprehensive data sets on biodiversity in Lake Victoria basin and explanatory notes

iii) A comprehensive meta-database on biodiversity in Lake Victoria basin
iv) Comprehensive information on existing gaps in information for planning, management and resource utilization
v) Information on socio-economic, institutional, legal and policy framework for biodiversity conservation
vi) Comprehensive information on changes in biodiversity over time using both timelines and trends.
vii) Fact sheets on thematic aspects of Lake Victoria biodiversity with photographs, sketches or illustrations as appropriate.
viii) Guidelines on institutional networks for data sharing and updates
ix) Draft guidelines on prototype Lake Victoria Biodiversity Database with user interface and access by various stakeholders.

Qualifications

Institutions or registered firms may apply for this consultancy provided that they meet the following criteria:

1. Bidders should be institutions or firms or employees of firms where research or conservation of biodiversity is one of the principle functions.

2. Groups of institutions or firms may team up to enhance their capacity for the consultancy provided that the Expression of Interest is submitted in the name of one Lead Institution which will take responsibility for implementation, coordination and delivery of outputs.

3. The Lead Institution must be based in the Lake Victoria Basin and recognized for competence in biodiversity research or conservation.

4. Bidders should demonstrate that they have previously successfully undertaken similar assignment in the Lake Victoria Basin with proven performance

5. The Team Leader and key members of the bidding team should have at least 10 years experience in research and/or conservation of biodiversity

6. Team composition should reflect a regional outlook, with at least one member from an institution based in a EAC country other than that of the Lead Institution.

7. Composition of the team members must have competency in the following areas of specialization with respect to biodiversity:
    i) Fisheries and fish biology
    ii) Socio-economics
    iii) Wetlands ecology
    iv) Aquatic ecology
    v) Genetics
    vi) Terrestrial ecology
    vii) Databases and database management
    viii) Legal, policy and institutional framework

8. All the Scientist MUST have a relevant PhD degree

Duration

The study is expected to take 30 working days

Beneficiaries

The Study is expected to benefits many institutions, organizations and individuals across the LVB. The main beneficiaries will include:

1. Lake Victoria Basin Commission and affiliate institutions;
2. Resource users
3. Resource Managers
4. Research Organizations, International Research Organizations, UNEP, UNESCO etc)
5. Policy Makers;
6. Institutional of higher learning.

Submission

Technical and Financial Proposals should be submitted on or before 30th May 2008 to the Secretary, LVBC Committee on Contracts, P.O. Box 1510, 40100, Re-Insurance Plaza 6th Floor, Kisumu, Kenya (preferably both in electronic and hard copy).