Environment for Development: An Ecosystems Assessment of Lake Victoria Basin Environmental and Socio-Economic Status, Trends and Human Vulnerabilities

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We regret any errors or omissions that may unwittingly have been made.

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Foreword

In relation to the development of an Environment Outlook Report of the Lake Victoria basin, a stakeholder workshop on Lake Victoria was convened by the Pan African START Secretariat (PASS) in September 2004, through funding from UNEP-DEWA and START through the United States National Science Foundation / US Climate Change Science Program (USNSF/USCCSP). The stakeholder workshop brought together a team of experts from riparian countries of the lake basin region to discuss the issues and scope of the Lake Victoria Basin Environment Outlook Report, including reaching consensus on the structure of the Report, themes to be covered, emerging issues, outlook, experts to write various sections, content of the Report and policy options for action. The expert input was invaluable and sincere appreciation is extended to this group. The Report was collated by the Pan African START Secretariat (PASS) as an input into the Africa Environment Outlook (AEO) 2 and Global Environmental Outlook (GEO) 4 reports produced by UNEP Division of Early Warning and Assessment (DEWA).

This publication of technical papers on Lake Victoria, which have been written by some of the experts who were party to the Stakeholders Workshop in 2004, goes hand in hand with the Lake Victoria Environment Outlook Report 2006 as an information resource document. A whole array of issues are covered, including such aspects as: people and livelihoods, health and nutrition, water and land resources, land cover and land use change, freshwater pollution, aquatic biodiversity, energy and environment, natural disasters, fisheries, environmental assets, and legal and institutional frameworks in the lake basin. Each of the papers, while focussing on a particular aspect, tackle the relevant elements of these broad issues to varying degrees, offering, therefore, a richly spiced and integrated perspective of the environmental concerns within the lake basin. We would like to thank all the reviewers as they gave very useful comments on the manuscripts.

Discussions on the social and policy dimensions of the Lake Victoria Basin centre on the inhabitants of the basin and their livelihood strategies, which are defined by environmental stewardship and natural resource utilization. The health of the basin's inhabitants is related to the environment and to the people's vulnerabilities and ability to cope with the diseases (such as malaria, cholera, bilharziasis, HIV/AIDS and other human and zoonotic ailments) and nutritional imbalances. The freshwater chapter identifies human socio-economic dependence on freshwater resources and their vulnerability, human and natural pressures on the freshwater resources, and relevant policy actions and institutional frameworks and mechanisms intended to alleviate freshwater degradation. The key land degradation issues, addressed using the pressures-states-impact-response (DPSIR) framework, include: escalating soil erosion, declining soil fertility, agro-chemical pollution, salinization and loss of land cover and their impacts on human and environmental security. An analysis of future scenarios of the Lake Victoria land resources and land use change is also presented based on plausible futures through long-term interactions between economic development and environment. The poor quality of Lake Victoria's water and its deteriorating ecology is linked to the rapid riparian population growth and consequent livelihood activities associated with farming and urbanization. To help stem this tide there is need for more inclusive stakeholder involvement in the lake's management and for establishment and implementation of policies that will address the water pollution concerns. The biological diversity of the lake and wetlands in the basin is known to be exceptional both in number of species and in their endemism. The paper on aquatic biodiversity presents an exhaustive analysis on the pertaining situation of the basic biodiversity in the Lake Victoria basin, and emphasises the need for more studies to ensure sustainability as a result of the ongoing natural resources exploitation. Energy needs in the lake basin are largely met through the use of land based resources and is key to facilitating the development of income generating opportunities, improving living standards, reducing poverty, and ensuring the protection of the environment. The link between the energy sector and the environment has also been related to the impact of energy development and use on environmental and human vulnerability. Droughts and floods are the most devastating natural hazards within the basin. The paper covering this topic

examines their social, economic and environmental consequences, human vulnerabilities, as well as opportunities for prevention, mitigation and management. The paper on conflicts over transboundary fisheries explains the reasons behind the conflicts as well as a long-term strategy being initiated to address them. It demonstrates that capacity building at the local level through the regional institutional framework on Lake Victoria is the best approach to address the challenges arising from a dynamic transboundary fishery. Legal and institutional frameworks are presented in four categories: namely: (1) recretoral or functional statutes; (2) cross-cutting laws; (3) Framework environmental law; and (4) regional instruments. The paper presents a case study of Kenya, from which lessons can be drawn for Uganda and Tanzania. The final paper presents a discussion on the valuation of environmental assets in the Lake basin. It identifies the environmental goods and services and provides comparisons between social and economic values. It also explores the link between environmental asset valuation and environmental resources accounting/natural resources accounting (NRA), environmental impact assessment (EIA) and cost benefit analysis (CBA).

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Social and Policy Framework: Context of People and Livelihood

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ABSTRACT

Discussions on social and policy dimensions of the Lake Victoria Basin (LVB) centre on the inhabitants of the basin and their livelihood strategies which are defined by environmental stewardship and natural resource utilization. This paper presents a contextual narrative of the people of the LVB and their livelihood. It sets the stage for an ecosystem assessment of the basin's social and economic implication of natural resource state, trends and vulnerabilities. The demographic characteristics and selected social indicators for the basin are presented with a focus on implications to sustainable resource management. A description of fishing together with other main occupational activities of the basin's inhabitants is presented with emphasis on strategies, impacts, challenges and vulnerabilities that the current resources extraction activities impose on the people and environment. Owing to the transboundary nature of the basin, it is recognised that the people and institutional framework of the basin including the East African Community (EAC) together with subsidiary arrangements such as the Lake Victoria Development Programme (LVDP) hold the key to a joint and sustainable management of the basin. The policy areas singled out as important include: ecosystems, natural resources and environment; production and income generation; living conditions and quality of life; population and demography; and governance and institutional order.

Keywords: *Socio-economics, policy framework, Lake Victoria basin, livelihoods, sustainable development*

INTRODUCTION

The livelihood of the Lake Victoria Basin (LVB) inhabitants who number around 30 million in the five (5) countries of Kenya, Uganda, Tanzania, Rwanda and Burundi is at the centre of the social and policy discussion. The Agenda 21, the Lake Victoria Development Vision and the Lake Victoria Fisheries Organisation (LVFO) all emphasise Sustainable Development. The newly revived East African Community's Lake Victoria Development Programme (LVDP) has developed a common vision of the LVB, which together with that of the LVFO are the main guiding institutions for the development and management of the LVB on behalf of the riparian states. While the LVFO is specific to fisheries for the whole lake, LVDP is concerned with the general development and management matters of the LVB. The two institutions perform the all-important role of bringing together the riparian partner states in terms of policy harmonisation for LVB resources management and utilisation. Further to these two institutions, two more projects were initiated during the late 1990s, namely the Lake Victoria Environmental Management Project (LVEMP) financed by the World Bank and the Global Environmental Facility (GEF). The other established in 1997 was the Lake Victoria Fisheries Research Project (LVFRP), with the objective of encouraging sustainable development of the LVB by assisting LVFO in the creation and implementation of a viable regional management of the lake fisheries (Odada and others 2003).

This paper articulates the socio-economic and policy context in which the inhabitants of LVB operate in meeting their livelihood goals. The paper is organised to include the population profile of the LVB and a discussion on people, natural resources, livelihoods and gender. The interaction of people with resources and the influence of culture and religion to natural resources use are also articulated. The paper concludes with a discussion of the policy framework for the management of LVB and imminent vulnerabilities of the LVB people.

POPULATION PROFILE OF THE LAKE VICTORIA BASIN (LVB)

Demographic and Ethnic Composition

The demographic composition of indigenous people around the lake is diverse but share similar livelihood sources. These include: Wahaya, Wasukuma, Wakerewe, Wazinza, Wakara, Wajita, Waruri, Wakurya, Waluo, Wazanaki, Suba, Wamaasai on the Tanzania side. On the Kenyan side include Luhya, Waluo, Kisii, Wakurya, Wamaasai, Suba, Kalenjin, Teso. In Uganda there are Luhya, Waluo, Baganda, Basoga, Teso, Kalenjin. In the urban centres around the lakeshores, there is a composition of settlers and indigenous people involved in commercial activities of industrial production and trading and other social services. Mostly they are brought together by civil service, commerce and employment motives. These settlers include Arabs, Asians, Nubians and other ethnic groupings from other parts of the region. The other two countries making up the LVB are Rwanda and Burundi.

Compared to other parts of the region, the LVB is more densely populated. The population size and growth rates in this region also are high (e.g. 3% for Tanzania between 1988 and 2002). The age distribution, which has important implications to labour force supply, shows a favourable structure in the sense that the dependency ratio is low with the lower end of the pyramid significantly favourable for future labour force. On the Tanzania side of the LVB the dependency ration is 106% (Tanzania population census, URT 2002) while for Uganda it is 120% (Republic of Uganda 1994) and Kenya 130% (CBS 2004). Table 1 shows selected population parameters for different parts of the basin.

Table 1: Population, household and average household sizes of districts in different countries of the lake basin.

Sub-Region	Population	Households	Average household size
Shinyanga	2,805.580	445,020	6.3
Kagera	2,033,888	394,128	5.2
Mwanza	2,942,148	495,400	5.9
Mara	1,368,602	246,600	5.5
Total/Average (Tanzania)	**9,150,218**	**1,581,148**	**5.725**
Central	6,200,944	1,290,977	4.8
Eastern	5,701,446	1,079,302	5.3
Western	5,442,399	966,7973	5.7
Total/Average (Uganda)	**17,344,789**	**3,337,072**	**5.3**
Nyanza	4,392,196	986,014	4.5
Rift Valley	6,987,036	1,494,984	4.6
Western	3,358,776	701,323	4.6
Total/Average (Kenya)	**14,738,008**	**3,164,321**	**4.6**

Source: URT 2002, Population and Household Census; Republic of Kenya 2001; CBS 2004 and UBS 2001.

The mean statistics for selected social indicators in the basin are shown in Table 2. Education attainment is below the national average on the Tanzania side of LVB, which includes the regions of Mwanza, Shinyanga, Mara and Kagera. The average number of those without formal education is 29% while the national average is 23%. In Uganda and Kenya it is 33% and 18% respectively. The health status for Tanzanian side of LVB in terms of delivery of health services is close to the national average: mean distance to a health centre or hospital is 21.9 kilometres while the national average is 21.3 kilometres. In Kenya and Uganda the distances are significantly lower than the national averages.

Table 2: Selected social indicators for the Lake Victoria Basin[1]

Administrative Region	Education (those without formal education - %)	Health (mean distance to hospital - km)	Land ownership (acres)	Basic needs poverty line
Kagera	25	25.1	4.0	29
Mara	24	13.4	8.0	46
Mwanza	27	30.1	6.8	48
Shinyanga	40	18.9	14	42
National average	23	21.3	5.3	36
LVB (Tanzania) Average	**29**	**21.9**	**8.2**	**41.3**
Central	23	21.5	3.2	25
Eastern	41	34.1	3.4	36
Western	35	42.5	4.7	38
National Average (Uganda)	37	32.4	5.4	39
LVB (Uganda) Average	**33**	**27.8**	**4.7**	**34**
Nyanza	14.3	12.4	3.35	70.9[a] [42.8][b]
Rift Valley	25.7	18.4	5.9	56.4 [35.6]
Western	14.8	10.8	3.8	66.1 [38.5]
National Average (Kenya)	49.3	24.5	3.95	52.6 [34.1]
LVB (Kenya) Average	**18.3**	**13.6**	**4.35**	**64.5 [39]**

Source: CBS 2004, Republic of Kenya 2000; SID 2004 and UBS 2001

Most of the inhabitants of the LVB are farmers (average of 73% for Tanzania). Despite the abundant land and fisheries resources, the inhabitants of the lake region are among the poorest in the region. For instance an average of 41.3% of the LVB (Tanzania) live below the Basic Needs Poverty Line while those on the Kenya side are 39% and the Uganda side 34%.

Other demographic aspects considered include gender especially the way men and women work together and the division of labour and how they share benefits from their contribution to production. Marital status is looked at in terms of the composition of households, whether polygamous or monogamous. The types of households do have implications on cultural values and beliefs. For instance polygamy is taken to be a sign of wealth and high social status in some communities. Population density has been increasing at a tremendous rate in the LVB Tanzania side with the highest rate of population increase witnessed between 1988 and 2002 (152% increase in population density for Mwanza, 153% for Kagera, 157% for Shinyanga and 140% for Mara). This coincided with the time of the Nile Perch boom period and "Gold rush" period, where an influx of people flooded the lakeshore towns of Mwanza where there are more fish processing plants and fishing business is higher. Gold and diamond resources attracted people to Shinyanga and Mwanza regions during this period due to liberalisation policies, which made these resources accessible by small scale as well as large scale mining companies.

Occupational Activities of LVB Inhabitants

There are several occupational activities which the people of the LVB are involved in and these include: fishing, farming, bee keeping, trading activities, quarrying and sand mining and mining of gold and other minerals.

1 [a] = Refers to income poverty in 2000. [b] = Refers to Human Poverty Index (HPI) in 2003. HPI measures human deprivation in basic dimensions of human poverty and is the proportion (%) of people left out of progress. HPI includes the adult literacy rate, the percentage of population expected to reach age 40 and overall economic provisioning. The latter is a composite of three indicators – percentage of people with access to safe water, percentage of people without access to health services and percentage of children under five years of age who are underweight.

Fishing is undertaken for both subsistence and commercial goals. Most of the fisherfolk have been fishing over the years as a source of their livelihood. In the past decade fishing became increasingly commercialised threatening even the nutrition source for the LVB inhabitants. Most fish and particularly Nile Perch is sold to fish processing plants or other agents as a result increased prices that are out of reach of most poor to average households. Fish frames from the processing plants are now common sources of nutrition to these households. Fish catch is also declining due to increased fishing effort and illegal fishing methods.

Agriculture by far is the main stay of the LVB inhabitants. Farming of food and cash crops is practiced in the LVB. Food crops include maize, bananas, cassava, sorghum, millet, rice, sweet potatoes and an assortment of vegetables and fruits. Main cash crops include coffee, cotton and sugar care. The contribution of the LVB to their respective economies is also significant in terms of GDP. On the Tanzania side of the LVB it is shown that the four lake regions of Shinyanga, Kagera, Mwanza and Mara contribute more than 22% of the country's GDP, increasing from 22.3% in 1992 to 24.6% on 2002 (Table 3).

Table 3: Contribution of LVB Tanzania Regions to the National Economy (%).

Region	1992	1995	2000	2002
Shinyanga	7.8	7.8	7.8	7.8
Kagera	3.8	3.8	3.9	3.8
Mwanza	7.3	7.3	8.6	9.7
Mara	3.4	3.4	3.7	3.3
Total	**22.3**	**22.3**	**24.0**	**24.6**

Source: National Accounts of Tanzania 1992-2002.

Livestock in the LVB is significant particularly in the Tanzania, Uganda, Rwanda and Burundi sides. The traditional way of livestock keeping is still practiced. This has some environmental implications, cultural traits and economic significance. However, with the declining open spaces for grazing and pressure for land, there is a need for adapting cattle rearing to new realities. In the natural resources utilization area, the LVB inhabitants also indulge in beekeeping for livelihood and commerce. Tourism is based on mainly wildlife. In this basin, the Serengeti, Maasai Mara, Owen falls and the source of the Nile at Jinja among others represent the wealth of tourist attractions of the LVB.

Mining is another natural resource-based activity in the LVB. Gold mining, quarrying and sand mining are some of the major mining activities. On the Tanzania side, gold mining is quite a big industry.[2] This, however, poses a threat to the Lake and its flora and fauna if it is not carried out in a responsible manner. Mercury, which is mainly used by small-scale miners for processing of gold, is a heavy metal which accumulates in the food chain and may be dangerous once the amounts accumulated are high and widespread. Ikingura and Akagi (1996) found evidence of low mercury concentrations in fish and human hair, lower than the WHO reference value, in Mgusu gold mine and the Nungwe Bay of the Lake Victoria goldfields of Tanzania. Living organisms in the water like fish may take it in small proportions from the contaminated water flowing from mining sites or riverbanks; human beings eat the fish and the metal accumulates in their bodies.

In the urban centres of the LVB like Kisumu, Kampala, Mwanza, Bukoba and Musoma, Jinja and Entebbe, commercial activity is bustling. In the lakeside towns of Kisumu, Musoma and Mwanza and Jinja and Entebbe, fish processing activities are common. Other commercial activities also provide the centrifugal forces pulling people to the basin. Informal sector activities are also increasing to cushion the unemployment resulting from government downsizing due to economic reform programmes being undertaken.

2 Gold mines of Geita, Kahama and Tarime are a case in point.

On the Tanzania side, failures in cash crop production of cotton and coffee in recent years have resulted in increased movement into the LVB, and to a change in occupational economic activities in favour of fishing and fish-related activities. Direct employment created by the Lake Victoria fisheries particularly of Nile Perch had increased from 35,291 people in 1993 to an estimated 87,821 in 2000 (Kulindwa 2001).

The 2002 census results for Tanzania show that households are now purchasing more and produce less of the food they consume as compared to 1991/92 census. Furthermore, the share of household consumption as represented by education and medical expenses has more than doubled since the last census. This indicates an increased dependence on the market and integration of more households to market economy and ultimately to the global economy. This means now people are more vulnerable to shocks and effects of the global economy than before. In the LVB this can easily be seen through the late 1990s Nile Perch fish export ban to Europe. Is it a good thing or a bad thing? Good or bad notwithstanding, caution must be exercised in the way plans are made for the development of the LVB people. Diversification of production and commercial activities has never been as crucial as it is today. Dependency on monoculture or single market destination can prove to be catastrophic.

PEOPLE, NATURAL RESOURCES, LIVELIHOODS AND GENDER

Description of Natural resources

The Lake basin area covers 193,000 km^2 with Tanzania occupying 44 per cent, Kenya 22 per cent, Uganda 16 per cent, Burundi 7 per cent and Rwanda 11 per cent. The size of the lake makes it a critical determinant of weather and climate in the region. The LVB is endowed with a wealth of natural resources, these include; people, land (abundant and fertile), forest resources, minerals, fish (particularly Nile Perch), wildlife (floral and fauna), rivers and streams and wetlands. Lake Victoria's importance to the region and globally is related to the following: it is the largest inland water fishing sanctuary, and a major inland water transport linkage for the three East Africa countries; it is a source of water for domestic, industrial and commercial purposes and a major reservoir for hydroelectric power generation; it is a major climate modulator in the region, also rich in biodiversity; and it is a major source of livelihood to people in and around the LVB.

Human Resources

The LVB is estimated to have around 30 million people. This includes Kenya, Uganda, Tanzania, Rwanda and Burundi. This is a huge resource which, if well utilized, could bring about major progress to the region. The status of the population is shown to be poor and mostly with low level of education. The potential for developing this resource is huge.

Soils

Good fertile land for farming is abundantly available in the LVB. However, this region has been adversely affected by market arrangements for major cash crops of cotton, coffee and sugarcane. The low prices offered by buyers in this region coupled with unfavourable weather conditions for these crops particularly cotton and coffee, have hampered production. There are different types of soils suitable for a variety of crops. Ferrasols are dominant in the Kagera region. This type of soil is characterized by strong acidity and very low base saturation. Vertisols cover a major part of Mwanza. These are dark-coloured clays, which expand and contract markedly with changes in moisture content, and develop deep vertical drying cracks. Agriculturally, they are intensively cultivated and highly productive in some areas. Yet in other areas they remain under grazing. Acrisols are common in Shinyanga region, and they are characterized by an argillic B horizon containing illuvial clay and clay skin with base structure < 50%. Nitosols and cambisols are found in both Mara and Mwanza (NEAP 1994). Kagera region is a high potential agricultural area, followed by Mara, Mwanza and Shinyanga, which rank as medium to low potential agricultural areas. The rainfall in this zone ranges from 1000 to 1500 mm per year. Food crops grown include banana, beans, bambara nuts, maize and cassava, sweet potatoes, sorghum, sunflowers, and rice. Intense agricultural activities have led to

clearance of vegetation, resulting in the exposure of the soil to erosion both by wind and rain water; for instance the rainfall erosivity in Muleba district is above 18,000 J/m^2/yr, this is among the highest in East Africa (Yanda and others 2001). The greater part of Kagera District in Kagera region is also considered to be very highly vulnerable to erosion due to the type of soils.

Forests

Natural vegetation cover is rapidly being degraded from the "cultivation steppe" of Mwanza, Shinyanga regions westwards, threatening protected areas in districts like Geita, Kahama, Biharamulo, Ngara and Karagwe. In the eastern parts of the Basin there is evidence of on going deforestation in Bunda, Serengeti, and Tarime districts as well as in the highly deforested districts like Kwimba, Magu, Misungwi, Musoma rural and part of Serengeti districts (Yanda and others 2001). In Mara, Mwanza, Kagera and Shinyanga regions of Tanzania, households rely on different energy sources for cooking (Table 4).

Table 4: Distribution of households by main energy source for cooking (%)

Energy Source	Mara	Mwanza	Kagera	Shinyanga
Fire wood	83	80	92	89
Charcoal	13	18	5	9
Paraffin	2	1	1	1
All other	2	1	1	1

Source: National Bureau of Statistics, Tanzania Household Budget Survey 2000/01.

Forestry and woodland resources in the LVB have declined considerably because of indiscriminate harvesting for wood fuel, timber and building poles. Fish curing, and charcoal making for domestic use, account for a significant amount of fuelwood use. Studies conducted in the region show that efforts to reforest the region have still a long way to go in order to show any meaningful impact. Table 5 shows the average area coverage of productive forests in Tanzania.

Table 5: Area Coverage of productive forests in Lake Victoria Basin (Tanzania)

Region	Productive forests	Protective forests	Total
Kagera	157,927.7	144,613.9	302,593.6
Mara	152.2	1,581.0	1,733.2
Shinyanga	783,434.5	5,121.9	788,556.4

Source: Natural Forest Hand Book for Tanzania Forest Policy, Planning and utilization.

Forests and woodlands in this region provide a variety of tangible and intangible goods and services. Among the tangible resources are timber for furniture and building of houses and boats. Forests and woodlands provide sanctuary to a variety of wild animals and other living organisms. Wood fuel, wild animals, fruits, vegetables, and medicinal herbs are available for the livelihood support of rural dwellers in the basin. Other tangible goods include grass for thatching and grazing of livestock. Forests and woodlands in the basin include: Bukoba, rain forest, Mwanza riverine woodland and rain forest in Ukerewe.

Wetlands

Wetlands, which have both ecological and hydrological functions have been intensively cultivated and overgrazed in Shinyanga, Mwanza, and Mara regions (Table 6). This has resulted in their degradation and thus they can no longer perform their ecological and hydrological function such as trapping of sediments and biodiversity conservation. Instead, these wetlands are now contributing to sediment flux into the lake.

Table 6: Large fresh water wetlands associated with Lake Victoria their status and species features

Name of wetland	Wetland type	Approximate size (km^2)	Conservation status	Special features
Lake Burigi	Shallow lake	70	Unprotected	Fisheries Agriculture and grazing
Upper Kagera	Shallow lake	350	Practically protected and controlled area	Wildlife Agriculture and grazing
L. Victoria	Swamp shore	68.890	Largely unprotected	Fisheries, Agriculture and Grazing
Mara System	Swamp and flood plain	300	Unprotected	Agriculture, fisheries and grazing

Minerals and Mining

LVB is well endowed with rich mineral deposits of gold and diamonds. Both large and small-scale mining activities are carried out. Mining is more common in Geita, Kahama, Biharamulo, Karagwe, Musoma, Tarime, Bunda and Misungwi districts. Deforestation and wanton land degradation is rampant in the mining areas. Small-scale mining of gold requires the use of a huge amount of logs, which are used to strengthen the ditches to avoid collapsing. Some of the ditches are as deep as 50m or more. In addition to the logs, the concentrated, large population in the mining sites increases the demand for wood for domestic use. Fire wood collection and charcoal making are supplementary activities that are conducted in the mining area in districts like Geita, Kahama, Tarime and Biharamulo. Charcoal making and tree felling for building purposes are very evident along the major routes linking mining sites to nearby major towns. Mining activities are not only associated with deforestation but also with destruction of the soil surface, by leaving open pits in the ground and covering the top soil with gravel and sub soils. In some areas the land is abandoned after the mining activities without any attempted rehabilitation of the land. Mining is also associated with population changes due to influx of migrants from various parts of the country, and health hazards threaten especially in the mining camps (Yanda and others 2001). Land degradation is experienced around mining sites, and the mining activities have led to water pollution in the lake basin. In areas such as Geita and Musoma in LVB, where small scale gold mining is taking place, there are risks of ground water and surface water contamination with mercury which is extensively used in the recovery of gold.

Fish

Lake Victoria is rich in biodiversity of which fisheries is a major resource for the riparian communities and for export (Okeyo-Owuor 1999). Lake Victoria is among the African Great lakes that are considered to be dynamically fragile ecosystems. During the last two decades the lake has encountered numerous problems and extensive resource exploitation, which has constrained its productivity resulting in the drastic decline of biodiversity in general and fisheries in particular. Among the factors that have led to the destruction of the native and endemic components of the lake include the following: intensive non-selective fishing, extreme change in the drainage basin vegetation, pollution due to industrialization and agricultural development and the introduction and invasion of exotic species. Despite the utilisation and pollution pressures experienced, Lake Victoria basin is still well endowed with fish resources; hence, it remains a major economic asset to both large and small-scale fishers and the regional economy in general. Processing of fish for the market has environmental implications especially with respect to the use of wood fuel for fish smoking as a way of preservation. This process requires a lot of wood. The implication of this high wood demand for fish preservation/processing is deforestation along the lakeshores and beyond (Yanda and others 2001).

Wildlife Resource

Wildlife is abundant in the LVB. The southern side of the basin has several national parks and game reserves, namely; Rumanyika Game Reserve in Kagera region, Biharamulo (1,300 km^2) and Burigi Game Reserves (2,200 km^2) in Kagera, Rubondo National Park (460 km^2) in Mwanza, Serengeti National Park in Tanzania and Maasai Mara on the Kenyan side, Maswa Game Reserve (220 km^2) in Shinyanga, Saanane Island Game Reserve (50 km^2) in Mwanza region and Ibanda Game Reserve in

Rwanda. These resources are widely used for tourism and as a source of livelihood particularly for game meat which makes up a significant proportion of nutritional requirements for those living around wildlife areas.

Livestock Keeping

The LVB has a favourable environment for raising both exotic and traditional cattle. Different production systems are prevalent in LVB. For instance in Karagwe District four distinct systems are practiced; first is the keeping of indigenous cattle on communal land set aside by village government, while the second system is a semi-nomadic system whereby larger herds of cattle are grazed on communal land and moved around depending on availability of pasture and water. The third system comprises of smallholder dairy cattle farmers who practice zero grazing. Lastly is the large-scale ranching system where beef cattle are reared in large numbers (Yanda 2001). In Mwanza region, livestock keeping is concentrated in Msalala and Nyanghwale Division – Geita District where serious overgrazing occurs. Watering points in these areas are not evenly distributed; as a result there is severe degradation along cattle routes and around watering points. Livestock keepers in Kwimba District, Mwanza region, use free range grazing systems on communal land leading to overgrazing. Recent observations show an increase in land use conflicts especially by cultivators and livestock grazing. This situation has been accelerated by the rapid expansion of farming activities into the traditional grazing areas basically due to population pressure (Yanda and others 2001).

Rivers

The main rivers in the Lake Victoria basin include, in Tanzania: the Kagera, Moyowosi (Shinyanga), Isanga, Duma, Simiyu, Mbalagati, Manonga, and Mara rivers in Kenya and Tanzania. In Kenya, the rivers include the Nyando, Nzoia, Yala, and Sondu-Miriu. These rivers are important for lake fisheries by providing spawning grounds for some types of fish, and by replenishing the lake with water and nutrients. They, however, also play a sediment and pollutant transport role from the catchment areas around the lake hence facilitating the lake's degradation.

Natural Resources Livelihood and Gender Dimension

A number of socio-economic studies have shown that there are gender differences in utilization of natural resources in the basin (Nakijoba 1996; Nanjunya 2001; Ochola and others 2000). Degradation of wetlands tends to affect men and women differently as evidenced by the impact of wetland reclamation in Kampala area. Nakijoba (1996) discovered that declining wetland resources are affecting women because traditionally division of labour among gender prescribe and charge women with the responsibility to certain social and economic chores for the family. In this case then, they are naturally the ones to utilise wetlands more than men do for their households' food and medicinal resources. This is also true in other part of LVB. The impact of resource decline or degradation like deforestation of natural forests or drying up of water sources do affect women more than men because women are traditionally expected to collect both water and fuelwood. The declining forests increase distances to collect firewood, while water pollution also means that people have to travel further distances to access clean water sources. The need to boil water results in increased use of firewood. Mean distances to collect firewood in rural areas of LVB (Tanzania) are: 1.9 km in Kagera and Mwanza, 4.2 km in Shinyanga, and 2.9 km for Mara (URT 2002).

POLICY FRAMEWORK FOR MANAGEMENT OF THE LAKE VICTORIA BASIN

The East African Community holds the key position for policy making for the management of the Lake Victoria basin resources. This is because the LVB is a Transboundary entity and needs a framework, which transcends national boundaries, for joint management as a shared resource. The Lake Victoria Development Programme (LVDP) has been established under the auspices of the East African Community to deal specifically with developmental and management issues of the Lake Victoria basin. However, the programme includes only the current members of the community and excludes other

members of the LVB such as Rwanda and Burundi. So far the programme has developed a regional vision for the development of the LVB. The vision, which aims at, "A prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits", is the result of the three national visions of Kenya, Tanzania and Uganda[3]. During the national vision development process, five policy areas plus a wide array of strategies and change indicators were identified. The policy areas were;

1. Ecosystems, natural resources and environment,
2. Production and income generation,
3. Living conditions and quality of life,
4. Population and demography, and,
5. Governance, institutions and policies.

Within each policy area, a number of strategies were highlighted. For the Policy Area 1, fish resources management, land use and natural resources, water and pollution control and waste management strategies are included. The Policy Area 2 "production and income generation", includes the promotion of sustainable exploitation of resources potential, strengthening of research and development, and improvement of access to natural resources. Under these strategies, gender issues of access to fisheries and mineral resources are given consideration. Poverty issues and vulnerability of LVB communities are listed as being of strategic importance in the Policy Area 3. Others include water supply and sanitation, health services, education and training and infrastructure. Demographic and social cultural strategies are included in Policy Area 4. These are population growth and migration, cultural change and social behaviour and practices. The last policy area (Policy Area 5) includes strategies on good governance and human rights, harmonisation of laws and policies of LVB partner states, institutional framework and devolution, law enforcement and security and gender issues where gender equality and positive gender relations are given prominence.

Implementation of joint activities in the LVB, however, already began before the establishment of the LVDP mainly through the two major projects of LVEMP and LVFO. The LVEMP was established through a Tripartite Agreement signed ten years ago on 5th August 1994 in Dar es Salaam[4]. The LVFO convention's signing followed in 1996. The LVFO also has a vision, which is essentially specific for fisheries matters. The issue of existence of multiple visions in the same basin by various actors was recognised by the LVDP and was accordingly accommodated so as to eliminate any inconsistencies, duplications and overlaps. Furthermore the full participation by all stakeholders in the vision and policy development process was given priority. This approach provides the opportunity for ownership, success and to a large extent ensures sustainability of the socio-economic and environmental development of the Lake Victoria basin.

VULNERABILITY OF COMMUNITIES IN LAKE VICTORIA BASIN WITH RESPECT TO ENVIRONMENTAL CHANGE

Four major areas of vulnerability for the inhabitants of the LVB are identified among the many which exist. These are natural and anthropogenic sources, which include drought, flooding, pollution of the lake and dependence on few export markets for fish. Drought occurrences in the basin appear to follow a 10-year cycle. In 1984, 1994 and 2004 drought has devastated vegetation, crops and livestock in the Kenyan side of the LVB. These incidences further stress the hydrological cycle and hence water availability, and cause food insecurity resulting from poor or no harvests. Flooding on the other hand is an annual event in Kenya now, which has come about due to conversion of wetlands, deforestation of the catchments and destruction of river embankments. The outcome of floods is, among others, displacement of people and destruction of their property causing food insecurity and loss of life. All these lead to increased poverty in the basin. Pollution on its part results into dwindling fish catches which lead to deficient nutrition, decline in income, and increased waterborne diseases.
Dependency on few fish exports markets for the Lake Victoria fisheries puts the fishing community and the inhabitants of the LVB in general at a delicate position particularly when fish exports contribute a large proportion of income to the region. Any event, such as the export ban which occurred in 1999

3 EAC, http://www.eac.int/LVDP/vision_LVDP.pdf
4 Ibid p2

due to water pollution and illegal fishing practices, causes a major shock to the economy in terms of employment, incomes and foreign exchange earnings for the region. Diversification of economic activity and of markets is highly recommended to stabilise the region's economy. The responses that have been instituted by individual communities, institutions and governments at sub-basin and basin scales are crucial as they have contributed to the basin's responses to the main environmental challenges and human vulnerabilities discussed in this paper.

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Health, Diseases, and Nutrition in the Lake Victoria basin

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ABSTRACT

The extent to which the pressures on the Lake Victoria basin environment impact the health and nutrition of the communities within the region is often not adequately addressed. The burden of diseases and constraints on the health facilities in basin can be traced to the state of the environment, vulnerabilities of communities and livelihood strategies. Predominant health issues in the basin are linked to unsafe water contaminated by microbial and chemical pollutants, poor disposal of human waste, and food insecurity while some of the health problems in the basin are exacerbated by climatic conditions, whose extremes overwhelm the community's coping capability. This paper documents the health related issues of the basin by relating the environment to the people's vulnerabilities and ability to cope with the diseases (such as malaria, cholera, bilharziasis, HIV/AIDS and other human and zoonotic ailments) and nutritional imbalances. Proper management of resources of the Lake Victoria basin needs to be urgently undertaken to enhance agricultural productivity and improve nutritional and health potential for the riparian communities. Detection of disease in this region calls for major human and material resources, such as well-equipped health centres and qualified staff. There is a need to integrate more strongly health policies into other development and natural resource utilization programs. There is need to continuously monitor and evaluate health and diseases trends in the basin using a Health and Demographic Surveillance System.

Keywords: *Health, nutrition, HIV/AIDS, Lake Victoria basin, water-borne disease, disease vulnerability, disease surveillance.*

INTRODUCTION

Lake Victoria, which is shared between the three East African countries of Uganda, Tanzania and Kenya, constitutes one of the most important and dynamic shared resources of the region. The lake has a catchment area that is inclusive of Rwanda and Burundi, and covers an area of approximately 193,000 $km^{2,}$ supporting close to 30 million people or approximately one third of the total population of Kenya, Uganda and Tanzania[5]. The wetlands of the Lake Victoria basin cover a significant area, with those in Kenya and Uganda constituting approximately 37% and 13% of the total surface area of the wetlands in the two countries. These wetlands, represented by swamps, rivers, and streams, and the surrounding terrestrial areas, as well as the human resources present a great potential for economic and social development of the region. Besides being a source of food, water, and recreation for the communities living around it, the lake offers important opportunities such as fisheries, transport and communication, water and energy, tourism, agriculture and mining. However, these same opportunities have created highly negative impacts, adversely affecting the economic and social status of the residents and resulting in a basin, which is still underdeveloped, struggling to overcome poverty, ignorance and diseases. The human population is high and continuing to grow, with expanded human settlements and urbanization without the accompanying proper planning and improved infrastructure facilities. Stakeholders in the region, who include the local communities, industrialists, the regional governments and various development partners, possess various levels of capabilities and different interests in ensuring the

5 http://www.lvemp.org/L_About%20L.Vic/about_lake_victoria.htm

proper management of the Lake basin resources. As the stakeholders pursue their various interests, they impact on the environment either negatively or positively. Pressures emerging from the diverse social and economic activities as well as from natural processes and phenomena, are increasing vulnerability of the riparian communities. The extent to which the pressures on the lake environment impact the health and nutrition of the communities within the region is often not adequately addressed. Africa, hosting approximately 11% of the world's population, was estimated to be bearing 24% of the world's burden of disease in 2001 (WHO 2003). According to the Millennium Development Goals of the United Nations, measured against baseline year 1990, all member states have pledged to undertake programs that will reduce by two thirds the mortality rate among children under five, reduce by three quarters the maternal mortality ratio, halt and begin to reverse the spread of HIV/AIDS, and halt and begin to reverse the incidence of malaria and other major diseases by the year 2015 (United Nations 2003). Many communities within the Lake Victoria basin currently lack the economic resources to meet these health-related millennium goals. Predominant health issues are linked to unsafe water contaminated by microbial and chemical pollutants, poor disposal of human waste, and food insecurity. Some of the health problems in the region are exacerbated by climatic conditions, whose extremes overwhelm the community's coping capability. Not to be ignored are also health issues related to emerging and other infectious diseases, accidents and internal and cross-border conflicts within the region.

HEALTH AND NUTRITION IN LAKE VICTORIA'S CHANGING ENVIRONMENT

Climate

Global climate change is estimated to be one of the biggest environmental threats over the coming century (Van Lieshout and others 2004). The Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report recorded that global warming of 1.4 – 5.8 ºC can be expected over the coming century. The report concluded that an increase in temperature with adequate rain will cause certain vector-borne diseases such as malaria, dengue, and leishmaniasis to extend to higher altitudes and higher latitudes in areas with limited or deteriorating public health infrastructure and where temperatures and rainfall patterns are permissive of disease transmission (IPCC 2001a). Githeko and others (2000) have reported that malaria is probably the most climate sensitive vector borne disease. The global average surface temperature has been reported to have increased significantly by +0.15±0.05ºC per decade since 1979, with the difference occurring mostly over the tropical and sub-tropical regions (IPCC 2001b). In the event of changes in climate variability, it is generally recognized that vector and water-borne diseases are very sensitive to warming and therefore are likely to be affected by climate change (Table 1).

Table 1: Major tropical vector-borne diseases and the likelihood of change in their distribution as a result of climate change[1]

Distribution Disease Change	Vector	Number at Risk (millions)	Number Infected or New Cases/Year	Present Distribution	Likelihood of Altered Distribution with Climate Change
Malaria	Mosquito	2,400	300-500 million	Tropics/subtropics	+++
Schistosomiasis	Water snail	600	200 million	Tropics/subtropics	++
Lymphatic filariasis	Mosquito	1,094	117 million	Tropics/subtropics	+
African trypanosomiasis	Tsetse fly	55	250,000-300,000 cases/yr	Tropical Africa	+
Dracunculiasis	Crustacean (copepod)	100	100,000/yr	South Asia/ Middle East/ Central-West Africa	?
Leishmaniasis	Phebotomine sand fly	350	12 million infected, 500,000 new cases/yr (2)	Asia/South Europe/Africa/America	+
Onchocerciasis	Blackfly	123	17.5 million	Africa/Latin America	++
American trypanosomiasis	Triatomine bug	100	18-20 million	Central-South America	+
Dengue	Mosquito	2,500	50 million/yr	Tropics/subtropics	++
Yellow fever	Mosquito	450	<5,000 cases/yr	Tropical South America and Africa	++

+ = likely; ++ = very likely; +++ = highly likely; ? = unknown.
(1) Top three entries are population prorated projections, based on 1989 estimates.
Sources: PAHO, 1994; WHO, 1994, 1995; Michael and Bundy, 1996; WHO statistics.

There has been much speculation and debate on the nature of climate variability within the East African region and whether climate change is exacerbating the malaria problem. With the ever-increasing evidence of global climate change, interest has developed in establishing whether this is occurring on a detectable scale in the Lake Victoria region, and what its short and long-term implications are for the region. Studies by different researchers currently conflict on this issue. A study, conducted by researchers from the University of Oxford in 2002, found "no significant changes" in long-term climate in the East African highlands (Hay and others 2002). An earlier study (Githeko and Ndegwa 2001), and a later analysis (Patz and others 2002), however, contrastingly concluded that the increase in the incidence of malaria in East Africa parallels warming trends over the last several decades (Patz and others 2002). The new analysis found a mean warming trend of 0.15 degrees Celsius per decade from 1970 to 1998 across the same East African region included in the previous study. Zhou and others (2004) reported that 12-63% (mean 36.1%) or the variance in the number of monthly malaria outpatients in a number of sites in the East African highlands is attributed to climate variability. Transmission of malaria in high altitude areas is limited by low temperature (Loevinsohn 1994, McMichael and others 1996, Martens 1999), and one of the conclusions of the International Panel on Climate Change is that with rising temperatures, there is likely to be an extension of distribution of malaria and an increase in the incidence within high altitude areas (McCarthy and others 2001). Studies are beginning to show an increased incidence of malaria in the Lake Victoria region (Githeko and Ndegwa 2001) and this implicates impacts of pressures that are currently occurring. This debate clearly is a wake up call for communities within the Lake Victoria region to consider the potential impacts of climate and health issues on their vulnerability and coping strategies.

Other diseases occurring in the region such as bilharzias and cholera are also sensitive to climatic conditions, although shifts in its epidemiology may take longer to become evident because the parasites are less sensitive to the effects of climate than malaria. Several studies have suggested that in East Africa, schistosomiasis is not a public health problem in areas with temperatures below 20ºC. Increases in temperatures due to climatic variability would thus similarly expand the geographical spread of schistosomiasis. Research has also demonstrated the association between cholera and climate change (Colwell 1996) by demonstrating the link between cholera and sea surface temperatures (SST). Changes in temperature variability are not the only culprit in the vicious cycle of climate and disease. In the event of changes in climate variability, it is recognized that vector and water-borne diseases are also very sensitive to increased precipitation. High rainfall in the Lake Victoria region is both a boon and bane, and is a constant cause of natural disasters in the form of floods and their associated negative impacts. Perennial improper surface and subsurface drainage and poor floodwater management leads to increased breeding sites for vector-borne diseases such as malaria and bilharzia (schistosomiasis).

Population density and distribution

It is generally acknowledged that unmanaged population growth, poverty and health are somewhat inextricably linked. Population size and distribution in the Lake Victoria region is a continuing source of pressure that is readily reflected in the health status of the riparian community. The human population density is high, well over 100/km^2 (Cohen and others 1996, cited from Odada and others 2004) and the rate of growth is among the highest in the world. In Kenya, the population density in parts of the Lake Victoria region is running to approximately 320/km^2 (LBDA 2004). This population comprises about 40% of the country's total population and is dominated by children and youth under 19 years of age, a group representing the dependency age group most vulnerable to endemic diseases like malaria, diarrhoea and water-borne diseases. Distribution of this population is highly dynamic and constantly changing. Increased rural to urban migration has led to intensified urbanization. There's a high degree of movement of businessmen between urban centres, movement of fishermen between fishing villages, and residents between the rural areas to urban centres for economic interests. There are a number of urban centres located along the lake in all the three riparian States. The major ones are Kisumu and Homa Bay in Kenya, Mwanza in Tanzania, and Jinja in Uganda. Apart from these major urban centres, there are smaller centres that support numerous other activities, such as the fishing villages.

Water Pollution and Water Quality

Freshwater is vital for good health and basic survival. It is not only important for food and energy production, but is essential to meet the basic needs of hygiene. Generally, unsanitary conditions are closely associated with scarcity of clean and potable water. It is estimated that only about 20% of Kenyan rural population has access to safe water, but for both Nyanza and Western provinces it is only 8% (LBDA 2004).

The lake is the final destination of factory effluent, oil and grease and raw sewage from the urban centres, and oil spillage from transportation is considered quite significant. Important pollution components of the lake include eutrophication, microbiological pollutants, chemical pollutants, and suspended solids, which result from direct activities on the lake, untreated municipal sewage, agricultural waste brought in by inflowing rivers, maritime transport waste, and runoff and storm waters inflow. The main water-borne diseases in the Lake Victoria region, which are influenced by scarcity of clean water, include cholera, typhoid, dysentery, and certain intestinal parasites. Faecal contamination of water also leads to bilharzia, the main water-contact disease in the Lake Victoria region. Increased human contact and exposure to the lake water in the cities and the fishing villages occurs through fish landing, trading, transport, recreational swimming, bathing, collecting water and washing household effects in the lake. Conditions at beach landing sites are unsanitary, and there is widespread faecal bacteria contamination and pesticide residues in fish, water and sediments. Economic and cultural values have in the past dictated poor faecal waste disposal mechanisms, with inadequate toilet facilities. In Kenya, intense water-contact activities such as car washing and sand harvesting have also increased around populated lakeshore towns, such as Kisumu town.

Car washing in Lake Victoria, Kisumu, Kenya.

Water contact by sand harvesters in Lake Victoria near Kisumu Kenya.

The lake has also been subjected to increased microbiological and heavy metal pollution, reduction in diversity of fish species, reduced levels of oxygen, increased salt loading, and emergence of water hyacinth, all of which eventually impact on the increased incidence of diseases and general health of the people.

Majority of factories in Kenya operate a treatment plant but wastewater treatment facilities are generally absent in Tanzania and Uganda. However, even in Kenya where treatment facilities exist, their efficiency should probably be subject to rigorous scrutiny. Increasing human population has created the need for greater quantities of agricultural products. This has led to the changing methods of farming from small-scale labour intensive, to mechanized farming that requires a high input of agricultural herbicides and pesticides. There is thus an increase in inflow of agricultural chemical residues, and heavy metal pollution from mining activities. Since the 1960s, phosphorus and nitrogen nutrient inflow has given rise to a five-fold increase in algae growth, being dominated by the potentially toxic blue-green variety, and

causing de-oxygenation and threatening the survival of deep water fish species. Preliminary findings of the Water Quality and Ecosystem Management Component of the Lake Victoria Environmental Management Project (LVEMP) – Tanzania indicate that near-shore areas along Mwanza and Bukoba and Musona towns show high BOD concentrations and faecal coliform counts, with poor sanitary conditions along the shoreline settlements presenting a local public health issue (Ministry of Water and Livestock Development/LVEMP 2004).

Water Hyacinth and Algal Blooms

Water Hyacinth (*Eichornia crassipes*) was first reported in Lake Victoria in Ugandan waters in 1988 and later spread to the other two East African countries (LVEMP 2004). The infestation extends to its uppermost point within the Kagera River system to the headwaters of Mukingwa River tributary[6]. Unchecked growth of water hyacinth is associated with a myriad of problems including the destruction of wetlands and waterways, degradation of water quality, preventing of fishing and recreational activities, and from a health point of view, is a haven for snakes, and has been reported to be a suitable habitat for disease vectors such as encephalitis, filariasis, and bilharzias (LVEMP 2004; Rao 1989; Anon. 1992; Raytheon and others 2002). The statistical link between water hyacinth and malaria and bilharzias is not yet well defined, but it has been shown that a type of filariasis in South East Asia is entirely linked to the presence of the aquatic weeds[7]. As water hyacinth blocks beach landing sites and prevents docking of boats, fishermen are forced to wade through it as they try to physically remove the weed and push the boats through the weed. Both activities increase contact with disease and snake infested water, consequently increasing the risk of snake bites and contact diseases such as schistosomiasis.

Algal blooms, dominated by the potentially toxic blue green variety have developed on the Lake Victoria, resulting in cause for concern. Blooms of algae deoxygenate deep water, resulting in fish death, fish migration, and reduced yield. They also produce toxins that cause forms of dermatitis (Ministry of Water and Livestock Development/LVEMP 2004).

Water hyacinth blocking the Kisumu ferry terminal, December 1997.
http://edcintl.cr.usgs.gov/waterhyacinth.html

Landing site heavily infested by Water Hyacinth, Lake Victoria, Uganda.
http://www.fao.org/waicent/faoinfo/agricult/agp/agpp/ipm/weeds

Exploitation of the Lake's resources

There is a heavy reliance upon the lake for food and water supply in Kenya, Uganda and Tanzania. Changes in population distribution, density and growth rate has had a direct relationship with overexploitation of

6 http://www.cleanlake.com/rwanda biological_control_program.htm
7 http://www.itdg.org/doc/technical_information_sevice/water_hyacinth_control

the lake's natural resources, with unsustainable utilization of the wetlands. The fisheries industry is a major economic driving force in the areas immediately bordering the lake, and is becoming increasingly commercialized. A drawback of the development of commercial fishing industry in the Lake Victoria basin has been the growth of large commercial operations of fish for export market. This has taken over the primary economic and nutritional resource of fish, originally controlled by small-scale fishers who processed the fish for local consumption. With the development of commercial fishing, local fishermen sell almost all their fish catch for export and this leaves the local populations with a high demand for fish, and only able to buy the carcasses from fish processing plants after filleting.

Local villagers also traditionally met their dietary requirements by depending on the small fish in the lake. With their depletion, malnutrition consequences such as Kwashiokor are often evident in children in lake communities. The introduction of the Nile Perch and the Nile Tilapia, and the use of unsustainable fishing practices such as the introduction of gill nets have altered the species composition of the fauna and flora of the lake. This has lead to the loss of locally favoured fish species, known for their medicinal and cultural values[8]. Many of the small fish originally found in plenty were specially adapted to eat algae and decaying plant material in the lake (Beadle 1974). Some species had also evolved to feed on the vector snails of schistosomiasis (Kaufman 1992).

There are other major economic activities that exploit the lakes natural resources along the beaches in the fishing villages in Kenya besides fishery. Harvesting of sand and papyrus for building and basketry, and catfish fingerlings (locally known as Nyapus in Kenya) for use as bait in long line fishing, especially Nile Perch fishing are common activities. Harvesting of catfish fingerlings has its downside as the harvesters wade into the water to get the fingerlings, directly exposing them to schistosomiasis and snake bites (WIFIP 2004).

Exploitation of mining resources is another area of health concern in the Lake Victoria basin. The region is endowed with a variety of minerals, metallic and non-metallic ore deposits such as gold, limestone, copper, iron, silver, rare earths, soapstone, quartz sand, chromium and lead. Uncoordinated and haphazard prospecting for these minerals occurs, and frequently leads to uneconomical and dangerous exploitation practices and accidents. Small-scale gold mining is increasing, especially in Tanzania, leading to some contamination with mercury. There have been a number of studies measuring mercury (Hg) concentrations in the lake water, fish, sediments, soil, and humans (Campbell and others 2003). These studies have reported total Hg concentrations in fish to be below those permissible by WHO standards and international marketing limits. However, concentrations in Nile perch between 3-10 kg, and especially over 10 kg were above WHO threshold concentrations for at-risk groups. Sediments and soil total mercury concentrations were within international guidelines.

The concentrations in urine and hair from human volunteers indicated that while gold miners and frequent skin-bleaching cream users were at risk of inorganic mercury poisoning, the rest of the population, including fishermen, was not. Some traces of heavy metals such as chromium and lead have been found in the lake, but the problem is not major. In Mwanza gulf, Tanzania, Cu, Hg, Pb, Cd, Cr and Zn were found in sediments, but not in dangerous concentrations (Kishe and Machiwa 2001). So far also, agrochemical residues have not been detected in concentrations that would cause health concerns. The presence of unacceptable concentrations of Hg in large fish, however, underline the need for regular monitoring and risk assessments to be carried out in the Lake Victoria catchment, since the same studies showed that fish consumption and soil geophagy constitute major sources of Hg for humans.

Malnutrition

The three summary indices of nutritional status are height-for-age, weight-for-height, and weight-for-age. Children who fall more than two standard deviations below the WHO reference median of these measurements are regarded as undernourished, while those who fall more than three standard deviations

8 http://www.lvemp.org/L_About%20L.Vic/about_lake_victoria.htm

below the reference median are considered severely undernourished. Height-for-age reflects stunting (short for age), and is a result of failure to receive adequate nutrition over an extended period and is also affected by recurrent or chronic illness. Weight-for-height measurements reflect wasting (or thin), and represents failure to receive adequate nutrition in the period immediately before the survey. It is typically the result of recent illness episodes, especially diarrhoea, or of a rapid deterioration in food supplies. Weight-for-age measurements reflect underweight, and are an indication of the effects of both acute and chronic malnutrition. In the Lake Victoria basin region in Kenya, a demographic survey showed that more that 30% of the children under 5 years were stunted, and more that 15% were underweight (Table 2). The 1988/1989 Uganda Demographic and Health Survey showed that almost half of the children under 5 years of age were stunted (45.5%) and almost one quarter were underweight (23%). A report by UNICEF (1989) indicated that approximately 60% of all deaths of children under 5 years of age in Uganda are directly or indirectly attributable to malnutrition.

Table 2: Nutritional Status of Children in the Lake Victoria Basin (Lwambo and others 2000; Kenya Demographic and Health Survey 2003)

	2 SD below median of WHO reference population		
Province	**Height-for-age (% Stunted)**	**Weight-for-Age (% Underweight)**	**Weight-for-height (% Wasted/Thin)**
Kenya: National average	30.7	20.2	5.6
Kenya: Nyanza province	30.8	15.4	2.3
Kenya: Western Province	32.6	24.4	8.0
Kenya: Rift Valley province	30.3	18.6	4.2
Tanzania: Mwanza gulf	30.5	15.8	2.5
Tanzania: Magu District	42.5	43	8.1

Child mortality

One of the best indicators of socio-economic level and quality of life is childhood mortality rates. In developing countries, one child in 10 dies before its fifth birthday, compared with 1 in 143 in high-income countries[9]. In Kenya, infant mortality and under-five mortality rates between 1984 and 2002 rose from 60/1000 and 89/1000 respectively to 78/1000 and 114/1000 (KDHS 2003). While the national infant mortality rate for Kenya was 74/1000 during the 1997 census, the rate for Nyanza, which lies in the lake basin was 135/1000. The rates in this lake region have been reported to be as high as 176/1000 and 259/1000 in some reports (McElroy and others 2001). 2002 infant mortality rate estimates for Tanzania stood at 104/1000 (UNCD 2005).

Zoonosis

The Lake Victoria region has a high density of cattle, favoured by a climate that is highly suitable to pasture growth. Zoonotic diseases are a constraint to successful cattle keeping. High levels of bovine tuberculosis infections have been reported in Uganda and Tanzania. The disease has been successfully contained for much of Kenya. The climate of the Lake Victoria region is also suitable for ticks and the associated tick-borne diseases. There is also African trypanosomiasis, whose major epidemiology factor is the human-tsetse fly contact. This interaction is influenced by an increasing tsetse fly density, changing feeding habits, expanding human development into tsetse fly–infested areas, and an increasing number of immunologically naïve persons in previously endemic areas, as human settlements encroach on previously uninhabited land. Sleeping sickness threatens over 60 million people in 36 countries of sub-Saharan Africa. Countries are placed by WHO into four categories in terms of prevalence. In each country the spatial distribution of the disease is very diverse; it is found in foci and micro-foci. Uganda and United Republic of Tanzania fall into the WHO's category of highly endemic countries, and yet in nearly 100 years, no appreciable progress has been made in tsetse and trypanosomiasis control in

9 http://ddp-ext.worldbank.org/ext/MDG/regions.do

Uganda (Okoth 1999). Kenya on the other hand belongs to countries where the endemic level is low and is restricted primarily to the Lake Victoria basin in Western and Nyanza provinces (Wellde and others 1989).

Poverty and Food Security

Sub-Saharan Africa is still steeped in poverty leaving it as the region with the largest proportion of people living below $1 a day, and unfortunately the number of poor is expected to rise from 313 million in 2001 to 340 million people by 2015[10]. Poverty, which is linked to cash-income generating sources, is widespread in the Lake Victoria basin particularly among the rural communities. Causes of poverty are numerous and varied, ranging from diseases, conflicts, lack of education and skills, and lack of infrastructure. According to a survey carried out by the Central Bureau of Statistics in Kenya, the region's mean household poverty stands at 46.4% (LBDA 2004). This makes it difficult to improve health and nutrition conditions in the region. There is limited infrastructure to cope with the ever- increasing population, and available health facilities in the region are few and inaccessible to many people. The roads in the region have continued to deteriorate over time making it difficult for residents in many parts of the basin to access health facilities. Approximately 21.7% of households in the Lake Victoria basin live at least 8 kilometres away from a health facility. Surveys have shown that 40% of the poor in Kenya did not seek medical care when they were sick due to inability to cover the cost of medical care, and 2.5% did not seek medical care when sick because they were constrained by distance to a health facility (LBDA 2004). In Uganda, a 1995/96 survey showed that poverty was high, and approximately 46% of the people live in absolute poverty and about 49% live within 5 km of a health service unit (MOH, Uganda National Health Policy).

Population density is one of the indicators of scarcity of land as a resource in the basin in Kenya (LBDA 2004), thus directly influencing food security. Rapid urbanization and high population growth (In Kenya – 6-fold within the last 4 decades.) is accompanied by negative economic growth and environmental degradation. The fundamental components of food security including availability, access and utilization differ in urban and rural settings, and also across socio-economic groups. Reliance on purchased food, especially in urban centres is a leading factor in household food security. Apart from human and animal diseases, crop diseases are also a threat to the ability of the region to produce adequate food supplies. For example, the papaya ringspot virus (PRSV) is a threat to the Lake Victoria basin papaya industry of Tanzania and Uganda where the rate of incidence ranges from 51-100% (USAID 2003).

Human Diseases

Malaria

Malaria is the most important tropical parasitic disease. Globally, WHO estimates that in their member States, malaria was responsible for 853,000 deaths/yr among the under 5 years of age, out of which 802,000 deaths/yr (18% of total deaths) were from the African region (World Health Report 2005). In the Lake Victoria basin, malaria transmission is intense and affected by climate and geography and often coincides with the rainy season. Although rural communities are particularly affected, urban areas are not spared either. There is a close link between urban malaria and drainage set-ups found within cities due to unplanned development. This creates the potential for an increase in malaria linked to rapid urbanization, especially in the poorly planned and poorly drained slum sectors of the cities and towns. According to 1999 Statistics, malaria constituted approximately 32% of the total outpatient cases in Nyanza and Western provinces in Kenya, followed by upper respiratory tract infections, skin diseases and diarrhoea. In the Magu district of the Lake region, malaria was on top of the list of top ten causes of mortality (Mwanga and others 2004). The most vulnerable groups to malaria in the population are children and pregnant women. A longitudinal cohort project undertaken between 1992 and 1994 in the Asembo bay area of Western Kenya, malaria parasite prevalence was reported to be 83% in 1-4 year

10 http://ddp-ext.worldbank.org/ext/MDG/regions.do.

old and 60% in 10-14 year olds (Blowland and others 1999). Anaemia was reported in the same study to be consistently associated with high-density infection of malaria in children under 10 years of age. More than half of all pregnant women had haemoglobin levels of Hb<11.0 g/dl, with up to 40% with a Hb of <8g/dl in the peak malaria season.

Schistosomiasis and other Intestinal Helminthes

More than 200 million people in 76 countries globally are estimated to be infected with schistosomiasis, and approximately 600 million people are at risk of infection. The presence of abundant surface water sources and the accompanying water-related activities particularly increase the chances of bilharzia transmission. In Kenya, Uganda and Tanzania, studies show that most transmission of the intestinal form of bilharzia tends to be closely confined to narrow zones along the shores of large bodies of water such as Lake Victoria where it is endemic and the intermediate host is found (Kabatereine and others 2001; Handzel and others 2003; Mwanga and others 2004; Lwambo 2004). Severe worm infections can lead to consequences including iron deficiency anaemia, protein energy malnutrition, stunting (a measure of chronic undernutrition), wasting (a measure of acute undernutrition), listlessness, and abdominal pain. Helminthic infections are very common within the lake region. A 2003 study in Asembo bay area within the Lake Victoria basin in Kenya (Handzel and others 2003) showed that sixty-three percent of students were infected with one or more geohelminths, with a prevalence of 42% for hookworms, 22.3% for ascaris and 17.9% for Trichuris. Another study in Busia district, which also falls within the Lake Victoria basin, also indicated that helminthic infections were exceptionally common among school children (Brooker and others 2000). They found an association between multiple infections with helminthes and intensity of infection, which may have consequences for nutritional status.

Diarrhoeal Diseases

Contamination of any drinking water increases the incidence of water-related diseases, such as cholera, amoebiasis, giardia, and cryptosporidium (Alterholt and others 1998). WHO estimates for diarrhoea related deaths/yr in under 5 years of age in their member States, within the African region is 701,000 representing 16% of total deaths (World Health Report 2005). Africa also accounted for 80% of the total reported number of cholera cases globally in 1997 according to WHO (1998). Cholera and bacillary dysentery have become important public health issues within the lake region in recent years. Ironically, the fishing industry is often a culprit in this cycle of disease and poor health, as it leads to unsanitary conditions at beach landing sites, sometimes causing sudden large outbreaks of cholera and dysentery due to contaminated water. Shapiro and others (1999) reported significant association between drinking water, bathing from Lake Victoria and the risk of infection with cholera.

Water samples from beach landing sites around Kisumu have shown a high level of faecal bacterial contamination. Lack of latrines in the region and a proliferation of faecal matter are also linked to widespread diarrhoea diseases. In surveys conducted in Western Kenya, drinking Lake Victoria water and sharing latrines between multiple households has been shown to increase the risk of bloody diarrhoea (Brooks and others 2003). Bacterial isolation rates during this study of sporadic bloody diarrhoea compare favourably with the rates reported from a cross-sectional survey in rural Uganda (Legros and others 1998), and during outbreaks in Burundi and Rwanda (Engels and others 1995). These water-related protozoal diseases tend to assume greater significance in HIV-infected individuals with immunocompromised status (Mwachari and others 1998).

Box 1: Example of Cholera outbreak

1. 1997 was a year of cholera outbreaks in Kenya, Uganda and Tanzania.
2. In a study between June 1997 and March 1998, there were 14,275 cholera admissions to hospitals in Nyanza province alone in Western Kenya.
3. Of these admissions, 547 deaths were reported.
4. One of the major risk factors identified for cholera among a sample of these patients was drinking water from Lake Victoria or a stream (Shapiro and others 1999).
5. Compared with other diarrhoea pathogens during this study, cholera was more common among persons living in a village bordering Lake Victoria.
6. In Burundi also, contaminated surface water is similarly identified as a major risk factor for cholera transmission (Birmingham and others 1997).

HIV/AIDS

HIV/AIDS was first reported in Tanzania in 1983, in Kenya in 1984 and Uganda in 1982. Two decades later, it has seen some reversal in its spread, with decreased national prevalence rates in the Lake Victoria riparian States, but it is still widespread and particularly so in fishing communities around Lake Victoria (Allison and Seeley 2004). It is a serious health problem, with great implications for the region's economy and a great contributor to poverty. AIDS drains both labour and capital from farming, seriously reducing harvest, and contributing to malnutrition. The head of state of Tanzania, President Benjamin Mkapa, declared HIV/AIDS a national disaster in 1999. In 2003, it was declared a national disaster in Kenya. HIV/AIDS is most prevalent in the most productive age (15-49). Therefore HIV/AIDS typically strikes the most productive members of the household first, immediately putting a strain on the family's ability to feed themselves and provide healthcare. ILO projected that HIV/AIDS may cause a drop in economic growth by as much as 25% by 2020 in Sub-Saharan Africa because of death and illness among workers in their most productive years (ILO 2000).

Mortality rates among HIV-infected adults in rural Tanzania was shown to be 15 times higher than those among HIV-negative adults, and HIV/AIDS was associated with nearly half of deaths at ages 15-44 years (Urassa and others 2001). Prevalence of HIV in the Lake Victoria basin stands at between 14%, and 16% compared with the national levels of between 6% and 7% (KDHS 2003), and is often linked to lifestyles. It is estimated that 21% of the total AIDS cases in Kenya are in Nyanza province within the Lake Victoria basin. Rates are particularly high (can be as high as 32.4%) among populations occupationally dependent on the lake. Prevalence in a survey of men and women age 13-34 years in rural area bordering the lake was shown to be 15%. Constraints to AIDS control include socio-cultural habits and slow pace of behaviour change and poverty. In a rural population in Tanzania between 1994-2000 (Mwaluko and others 2003), trends in HIV and sexual behaviour show a lack of change in sexual behaviour, highlighting the inadequacy of some interventions in curbing the growth of the epidemic.

Health and nutrition among those displaced by natural disasters and war

Malnutrition, disease and lack of food and water are the greatest challenges that face and organizations charged with the welfare of those individuals displaced by natural disasters, internal strife and cross-border wars. All three riparian communities are frequently faced with the need to support groups of displaced populations on short and/or long-term basis, such as those of Budalangi flood victims in Kenya, and war refugees in Uganda and Tanzania. Humanitarian assistance is not keeping up with the needs, and heavy use and limited maintenance of the transportation systems severely hampers delivery of food and non-food supplies, adversely affecting the health status of those affected by strife.

RESPONSES TO ADVERSE IMPACTS AND INCREASES IN VULNERABILITY

Proper management of resources of the Lake Victoria basin needs to be urgently undertaken to enhance agricultural productivity and improve nutritional and health potential for the riparian communities. A good place to start is whether there are policies and legal frameworks that act as guidelines to communities in

the Lake Victoria for the efficient management of available resources in a manner that will improve the health of the residents of the basin. All the countries in the region have policies and legislation to regulate the utilization of the Lake Victoria resources and deter environmental mismanagement. Enforcement regulations, however, tend to be weak or lacking, leading to ineffective implementation. The Lake Victoria Environmental Management Plan was initiated in Kenya, Uganda and Tanzania, in 1994 under the auspices of the Global Environment Facility.[11] The Lake Victoria Environmental Management Project (LVEMP) is an important initiative of the three riparian states to try and reverse the adverse impacts that have so far gone unchecked for so many years. This coordinated effort to curtail the current poor wetlands management encompasses management of fisheries and industrial and municipal wastes, control of water hyacinth, water quality monitoring, conservation of biodiversity, and sustainable land use. The Lake Victoria Development Programme (LVDP) has effected National Focal Points in the ministries of Partner States, which are responsible for Lake Victoria development (Odada and others 2004). Non-governmental organizations are also involved in implementing rural domestic water supply and health and sanitation programs.

There have been various management activities implemented by the governments of Kenya, Tanzania, and Uganda, with support from international partners, to review, evaluate and develop a Regional Water Hyacinth Management Plan. Together with Rwanda, these countries have begun to coordinate management efforts through regional organizations or projects. Rwanda implemented a *Neochetina* weevil species rearing and release effort in 2000 (Agaba and others 2001). Despite all the negative impacts of water hyacinth some of the practical applications suggested include water purification, fertilizers, animal fodder and fish feed.

Detection of disease in this region calls for major human and material resources, such as well-equipped health centres and qualified staff. For example, although malaria is curable if promptly diagnosed and adequately treated, it kills more people than any other communicable disease except tuberculosis, killing approximately one child every 30 seconds. Most people with many of the other human diseases occurring in the lake basin such as cholera and other diarrhoea diseases in children, and even sleeping sickness in some parts of the basin, die before they can ever be diagnosed. There are a number of disease surveillance centres that have come into operation, and which are strongly supplementing and strengthening the efforts of the national governments to monitor disease outbreaks. One such is the International Emerging Infections Program located in Kisumu, Western Kenya to deal with surveillance, investigating outbreaks, and intervening. Their quick mobilization during the recent outbreak of suspected leptospirosis in Western Kenya is an example of how the riparian states would benefit from strengthening disease outbreaks policies.

Like many other regions in developing nations, the ability of communities in the Lake Victoria basin to construct and implement effective health policies is plagued with lack of adequate population health and vital events information. Dependable national data sources that would allow for evaluation of national or regional health and disease trends are lacking, and thus policies are sometimes based on inadequate and biased information.

HIV/AIDS support services have been developed in the Lake Victoria riparian states gradually over time. Regional and national institutional frameworks also exist. Developing and promoting protective behaviours, adolescent health, and preventing and treating of Sexually Transmitted Infections can be a powerful tool in the fight against HIV/AIDS. For example the National HIV/AIDS Multisectoral Strategy Framework was recently formulated in line with the Tanzania National Policy on HIV/AIDS of 2001. Its objectives are to strengthen a multisectoral approach, ensure political and government commitment in the prevention of transmission, encourage voluntary HIV testing, increase care for persons living with HIV/AIDS and their families, enhance research efforts, and ensure the revision and creation of legislation on HIV/AIDS (Beckman and Rai 2004). Other areas of HIV/AIDS prevention available are mother-to-child transmission (PMTCT), Voluntary counselling and testing (VCT), and reduction in number of sexual

11 http://www.grida.no/climate/ipcc/regional/038.htm

partners. Studies in Tanzania illustrate the significance of this strategy (Ng'weshemi and others 1996). Access to anti-retroviral drugs (ARVs), VCT, TB/HIV programme and service links also exists in the Lake basin regions. Proper implementation and wider distribution of these services can also be a very powerful control and mitigation tool.

Malaria control involves a number of different approaches. These include protection against infection through prophylaxis, control of development of disease in infected individuals, personal protection through protective clothing, repellents, and bednets, community/population protection through insecticide spraying and environmental management. The effectiveness of insecticide-treated bednets in reducing morbidity and mortality from malaria has been documented (Choi and others 1995; WHO 2000). This can therefore be exploited in the fight against the disease. Drug resistance often impedes progress in the fight against diseases in the Lake Victoria region. For example, high-grade chloroquine resistance is widespread in the lake region.

Cholera and other diarrhoeal diseases are highly preventable diseases, whose only requirement is proper sanitation and safe drinking water to significantly reduce their transmission in a community. Cholera epidemic control and preventive measures include hygienic disposal of human faeces, adequate supply of safe drinking water and good food hygiene. Although less than 10% of persons harbouring the cholera bacteria develop typical cholera with signs of moderate or severe dehydration, case-fatality rates, which can be limited to less than 1% in a community with well established diarrhoeal disease control programme, can rise to as high as 50% in an unprepared community. In Kenya, the Ministry of Health has a National Cholera Task Force in collaboration with similar task forces set up at provincial and district levels[12]. Such task forces can however be greatly hampered by the poor infrastructure in the basin coupled with poor coping strategies within the impoverished communities. As in the case of malaria drug resistance, there are records of resistance to antibiotics by cholera bacteria (Shapiro and others 2001).

Geohelminths can also be targeted for control using various methods. In their resolution 54.19, WHO endorses mass school-based deworming programs for intestinal helminthes in areas with infection prevalence over fifty percent, since this eliminates the need for costly individual parasitological screening (Warren and others 1993, WHO 1992). School-based helminth control programmes have been identified as one of the most cost-effective health interventions (Partnership for Child Development 1998). Targeted drug distribution strategies can be implemented for either schools or entire communities in the endemic areas, such as treatment of all children living within 4 km of Lake Victoria for both geohelminths and schistosomiasis. If school health programs are developed as part of community partnerships, they can provide one of the most cost-effective ways to reach all age groups in the community. There is the draw-back that non-school going children would be omitted, but treatment coverage would be large and beneficial. Other regions of the world such as Egypt, China, Brazil, and Morocco have had good success with schistosomiasis control. This should be viewed as encouragement to attempt well-planned strategies for the Lake region.

There is great potential for fish farming even in the face of such an abundance of natural waters of the lake. Some groups are setting up precedence with this. In Kenya the Women in the Fishing Industry Project (WIFIP) is training women on the management of a Catfish propagation project. Apart from protecting the women from wading in disease and snake-infested waters, this is an income generating activity and conserves the wetlands.

Lessons can be learned from other regions in the world. The development of transgenic papaya saved the papaya industry in Hawaii from severe Papaya Ringspot Virus (PRSV) The same virus threatens the Lake Victoria basin papaya industry in Tanzania and Uganda with rates of incidence ranging from 51-100% (USAID 2003). Continuing development of disease resistant crops such as papaya resistant to papaya ringspot virus can provide effective control of the disease and stem some of the malnutrition

12 http://www.who.int/crs/don/1999_01_20/en/

in the region. Due to pressure of population, irrigation has potential in the region to cover food deficits. However, this would have to be accompanied by water-related disease prevention and control in-built strategies.

CONCLUSIONS AND RECOMMENDATIONS

The Lake has a direct influence on the health and nutritional status of the riparian populations, with much of the influence tending towards increased water-related diseases. Currently, capacity to cope is low, and the pressures on the environment and the lake, which result in compromised health status and food insecurity, continue to rise.

The common defence of regional health security requires a regional and global partnership. The aim should be to contain known infectious disease risks, to detect and respond to unexpected infectious disease risks and to improve preparedness and public health infrastructure. Reversal of the existing unacceptable social-economic and environmental status of the lake basin region will require clear identification of opportunities available, in order to avoid or mitigate potentially adverse environmental impacts and to identify opportunities for beneficial impacts. Fortunately, the East African communities, which form the Lake Victoria basin and its catchment area realize the urgent need to set up systems that will encourage the management of the basin in a sustainable manner to their benefit. Community involvement and participation in health issues that affect them should be encouraged. With proper management, the perennial flows of the rivers and floods can be harnessed to enhance agricultural productivity, and provide safe water supplies to the people of the region.

Box 2: Recommendations of Refugees International on Coping Strategies for the War-Displaced in Tanzania.

1. **To ease the impact of the food shortages: The government of Tanzania consider providing additional land to the refugees for use as kitchen gardens**
2. **To ease the impact of the food pipeline break: Donors should recognize the sizable refugee population that Tanzania is hosting, and consider providing funds for local and regional procurement of food and non-food items, e.g. maize may be purchased in Tanzania and corn-soy blend may be purchased in Kenya**
3. **WFP consider launching a Special Operations Project Appeal to fund the cost of emergency repairs and management improvements needed to facilitate transport of relief goods in the Dar es Salaam and Mombasa corridors.**
4. **Donors resume funding for non-food items, such as soap, medical equipment and medicines, especially malaria medication.**

There is a need to integrate, more strongly, health policies into other development programs. Parallel pursuance of poverty alleviation, population growth, and health policies should be reassessed to find linkages that can be exploited for maximum impacts. Accurate, reliable and continuously updated information bases that will assist in drawing up of workable strategies for better management of the lake can be invaluable. These should include disease distribution maps and models. For such bases to be useful, it is necessary to have continuous, regular monitoring for health and disease status of the communities in the region. One of the tools that can be implemented and utilized in the Lake Victoria basin to monitor and evaluate health and diseases trends in the region is the Health and Demographic surveillance System, which is a longitudinal population-based health and vital event registration system that monitors demographic and health events in a geographically defined population with timely production of data. From a health point of view, this allows for easy and clear definition of risks of health events for individuals over time. Health data bases will then enable the development of risk assessment strategies, early warning systems for disease outbreaks, and workable coping strategies.

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Freshwater related issues of Lake Victoria basin

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ABSTRACT

Virtually all the features of Lake Victoria basin including vegetation cover, livestock, human population and all socio-economic livelihood activities are fundamentally influenced by the quality and quantity of its freshwater resources. This review addresses a selection of the freshwater related aspects to illustrate man's interrelationships with and dependence on freshwater resources in the basin. Freshwater related aspects selected include rainfall, water for domestic use, water for production, wetland ecosystems, riverine ecosystems and lake ecosystems. The paper also identifies human socio-economic dependence on the selected freshwater related aspects, the human and natural pressures on the freshwater resources, the resultant man-induced environmental impacts on the freshwater resources, the human vulnerability to the impacts, and relevant policy actions and institutional frameworks and mechanisms (coping strategies) intended to alleviate human and natural environmental impacts on freshwater quality and quality, and reduce human vulnerability. Because the people of the Lake Victoria basin have become increasingly vulnerable to environmental change due to impacts of natural processes and inappropriate human actions on freshwater resources over the last two decades, the paper asserts that there is need for decisive and appropriate actions to reduce vulnerability and increase human security by strengthening existing coping strategies and implementing other environmentally sound water use practices.

Keyword: *Lake Victoria basin, freshwater, water quality, pollution, water-borne diseases, domestic water supply, water hyacinth*

INTRODUCTION

Lake Victoria basin

The Lake Victoria basin, shared by Kenya, Tanzania, Uganda, Rwanda and Burundi, covers an area of about 184,000 km^2. The basin comprises a variety of geographical features. Mountainous terrain topped with patches of indigenous tropical forest fringes parts of the basin. The rest of the basin consists of extensive often undulating plains covered by patchwork of woodland, savannah grasslands and large tracts of several wetland types. Much of the indigenous vegetation has, however, been transformed through intense land use pressure. Lake Victoria basin supports a rapidly growing population currently estimated at about 32 million people and is, therefore, one of the most densely populated zones of the eastern Africa region. Small-scale rain-fed agriculture based on a variety of food crops including maize, bananas, sorghum, beans; and cash crops such as coffee, tea and cotton dominate the traditional crop sub-sector. Some plantation agriculture of mainly sugarcane is practiced in the Kenyan and Ugandan sides of the basin. Nomadic livestock husbandry occurs throughout the basin while large tracts of wildlife reserves such as Serengeti National Park (Tanzania), Lake Mburo Game Reserve (Uganda) and Akagera National Park (Rwanda) are partly or wholly located in the basin. Fishing is a major socio-economic activity that provides for over two million people in terms of food and employment, and earns substantial income in foreign exchange to Kenya, Tanzania and Uganda. The basin freshwater resources dominated by the lake itself are the single most important natural resources supporting the livelihood of its inhabitants.

Lake Victoria, the second largest freshwater body in the world (area 68,800 km^2, maximum depth 84 m; mean depth 40m, volume 2,760 km^3 and shoreline development about 3,440 km), is the dominant and central surface water reservoir in the basin (Hutchinson 1957; Beadle 1972; Hecky and Bugenyi 1992). Most of the large rivers in the basin drain directly into Lake Victoria. The major rivers that drain the Lake Victoria catchments in Kenya include the Nzoia, Gucha-Migori, Sondu, Yala and Nyando; in Tanzania they are the Kagera, Simyu, Mara, Issanga, and Biharamulo; while River Kagera, the largest and longest in the basin drains Rwanda and Burundi. The confluence of two large headstreams, the Ruvubu and the Nyabarongo forms River Kagera. Numerous other smaller rivers and streams empty direct into Lake Victoria in Uganda, Tanzania and Kenya. The largest contribution to the water input into Lake Victoria, estimated at 82% (COWI 2002) is through direct rainfall to the lake surface (68,800 km^2) while the rest is from the catchments as surface runoff and subterranean input.

Scope and Objectives

The discussions in this contribution to the ecosystems outlook of the Lake Victoria basin are based on the assumption that the people of the Lake Victoria basin have become increasingly vulnerable to environmental change due to impacts of natural processes and inappropriate human actions on freshwater resources over the last two decades. There is therefore, need for decisive and appropriate actions to reduce vulnerability and increase human security by strengthening existing coping strategies and implementing other environmentally sound water use practices. In line with the above basic assumption, the objectives of this review of the thematic area on freshwater related issues are:

- description of the selected freshwater related aspects in Lake Victoria basin;
- identification of human socio-economic dependence on the selected freshwater related aspects;
- identification of human and natural pressures on the freshwater related aspects resulting from the socio-economic dependence;
- identification of resultant man induced environmental impacts on the freshwater related aspects,
- identification of human vulnerability to the man-induced environmental impacts on the freshwater related aspects;
- compilation of policy actions and institutional frameworks and mechanisms (coping strategies) intended to alleviate human and natural environmental impacts on freshwater related aspects, and on human vulnerability;

FRESHWATER ISSUES

Human dependence, pressures and environmental impacts

Surface water systems and groundwater aquifers constitute the main freshwater reservoirs in the basin. The major surface water ecosystems are mainly constituted by the Lake Victoria; the affluent rivers, the extensive floodplain and the lakeshore wetland habitats. Almost all freshwater habitats in the basin are associated with Lake Victoria, the central reservoir. The groundwater aquifer systems in the basin constitute a relatively little understood but vital water reservoir especially in the rural setting.

Rainfall

Rainfall is the primary source of freshwater reserves in Lake Victoria basin. The reserves occur as surface water in lakes, rivers, streams, and wetlands, and as groundwater in aquifers. Considerable rainfall variability in intensity and spatial reliability is experienced in most parts of the basin. In Uganda for example, national historical rainfall data shows a large spatial mean annual range of 600 – 2000 mm, which generally decreases with increasing distance from Lake Victoria (Ministry of Natural Resources 1995). Highest precipitation in the basin occurs in the mountain ranges and in some islands of Lake Victoria. Observations similar to Uganda's experience apply throughout the lake basin. Rainfall patterns determine local land use potential and influence population distribution in Uganda (Kahangire and Lubanga 2001) and, possibly throughout the entire Lake Victoria basin.

Human dependence, pressures and environmental impacts on rainfall

Human dependence on rainfall is basic to socio-economic development in the basin where rain-fed agriculture is the main source of food and income. A direct empirical relationship exists between human population pressure and high rainfall reliability and intensity in various areas of the basin. Densely populated basin zones of Mt Elgon districts in Uganda and Kenya, the Kisii highlands of Kenya and much of Rwanda receive relatively higher precipitation. Catchment forestry is a vital resource in the areas in both monetary and environmental terms. On the other hand the drier expansive parts of western Tanzania along the shores of Lake Victoria are sparsely populated and mostly practice nomadic livestock husbandry and grow drought resistant crops. Unsustainable land use related to high population densities and poor land use practices often lead to environmental degradation involving extensive devegetation of rangelands and degradation of catchment forestry. Destruction of catchment forest through unsustainable land use and instances of climate change and climate variability are linked to the disruption of rainfall patterns, and to the extreme events of severe droughts and floods.

Domestic water supply

The water resources of the basin are not evenly distributed throughout the basin and available quantities are highly variable in time and space. The population in the large urban centres predominantly uses surface water especially from Lake Victoria. The bulk of the population, which resides in the rural setting plus people in rural settlements depend on surface water from streams and swamps as well as from underground aquifers. Drinking water is an indispensable resource and freshwater is essential for cooking and washing. Humans are, therefore, totally dependent on domestic water supply. Accessibility to water for domestic use is a key determinant of the location of human settlements and hence, of the demographic trends of a given country. The relative abundance of freshwater in the Lake Victoria basin is one of the key factors influencing the increasingly rapid population build up in the basin (currently estimated at 32 million). The large cities in the basin (Kampala, Kisumu, Mwanza Bukoba) are located at the shores of Lake Victoria. Other large towns like Masaka and Mbarara in Uganda are located at a permanent water source (wetland and river, respectively). There is disparity in population distribution related to availably of good quality water in adequate quantities. For example the Uganda portion of the basin, which is generally endowed with plentiful supply of readily accessible surface water, is more densely populated than the relatively drier lake basin in Tanzania. Similarly, development of groundwater in the drier rural setting attracts settlement in those areas to the extent that rural towns develop close to centres with adequate yields of potable groundwater.

Pressures and environmental impacts on domestic water supply

Human pressures and impacts on domestic water resources may affect their quantity and quality. Faecal contamination is one of the commonest surface water quality problems especially in the rural setting, where sanitation is generally poor. Unprotected wells and springs exposed to contaminated storm water are particularly vulnerable especially at the onset of the rainy season. Groundwater, in heavily settled areas where pit latrines are not properly sited relative to the water sources, is often contaminated with faecal coliforms. Siltation of domestic watercourses and sources such as streams, wetlands, wells and springs. Unsustainable farming practices especially in the hilly zones of the Victoria Lake basin generate serious soil erosion. The farming practices are often characterized by ineffective land use planning, serious devegetation and inappropriate methods of cultivation such as un-terraced tilling of steep slopes. Other sources of contaminants of water for domestic use include mining (associated with heavy metals), municipal sewage and industrial effluents (excess nutrients, faecal coliforms, BOD and heavy metals), in situations where management of contaminants is insufficient or totally lacking.

Prolonged drought is probably the most widespread environmental pressure with the most devastating impacts on water quantity. In general terms, most parts of the Lake Victoria basin experience an annual dry spell during the months of December, January and February. The impacts of the annual dry season on water resources availability varies depending on the resource endowment of a given zone. While the dry spell is hardly noticed in zones with abundant supply of water, drier areas may experience significant reduction in surface water levels in wetlands and streams. Groundwater yields may also decline. Normal

water quantities are often restored with the rainy season. Periodically, however, the basin experiences prolonged droughts that disrupt domestic water supply as well as water for production over large zones. Wetlands with moderated water storage capacity and streams dry up. Groundwater tables drop drastically leaving dry springs and shallow wells. Some boreholes may dry up too or suffer drastic reduction in water yield. Prolonged drought is particularly detrimental to the generally drier zones of the Lake Victoria basin. In Uganda, Mbarara and Ntungamo districts, which constitute the southeastern arm of the mostly water deficient 'cattle corridor' (NEMA 1997), is particularly prone. Frequency of prolonged drought events supposedly linked to climate change are said to be on the increase. Instances of human induced pressures on water quantity occur in the event of excessive abstraction of ground water and degradation of wetland buffers. Population pressure is a major driving force in both cases. Excessive abstraction of groundwater may, however, be the result of inaccurate assessment of the water yield potential especially in cases of motorized water extraction.

Human Dependence on Water for Production

Water for production is used in this paper to refer to water abstracted, harvested, for example, by gravity schemes or diverted from natural reservoirs such as lakes and rivers or from artificial impoundments, to support crop production, livestock husbandry or fish farming. Lake Victoria basin is endowed with abundant sources of surface water for production but the distribution of the surface water reservoirs is, however, not even. Underground aquifers are the alternative sources of water for livestock especially in the drier zones of the basin but the yield of groundwater is, however, often insufficient for purposes like irrigation which require large quantities of water. In Uganda, productive aquifers are largely found in weathered bedrock and regolith overlying crystalline basement rock and in faults and fractures in the basement (NEMA 1997). Groundwater aquifers are fairly widely distributed all over most of the country and probably in the rest of the Lake Victoria basin but only limited effort has been made to determine their full extent and water reserve. Available information for Uganda indicates that most aquifers in the country are of limited spatial extent and have comparatively low yield (0.5 to 5 m^3/hour) with variable discharge (Kahangire and Lubanga 2001; Ministry of Natural Resources 1995). On the other hand, while the potential for irrigation is high in many zones such as areas close to Lake Victoria and along the affluent rivers, agricultural production in the Lake Victoria basin is predominantly rain-fed. Irrigation is highly limited and is restricted to a few crops such as flower gardens in Uganda and sugarcane and rice plantations in Kenya. Similarly, livestock husbandry in the basin is more dependent on natural surface water sources than on man's innovations to provide water for production. In some drier zones of the basin, however, provision of water for livestock has been in place for decades. In traditional cattle keeping districts of Mbarara and Ntungamo in southeastern Uganda, which generally experience low rainfall reliability and intermittent stream flows, water harvesting into communal reservoirs to support large herds of livestock was developed as early as the 1950s (Kahangire and Lubanga 2001). Groundwater abstraction is through boreholes and shallow wells located at convenient watering points in communal rangelands or on private livestock farms.

Cultivation of seasonal wetlands for dry season gardening and conversion of even the permanent zones for sustained crop and dairy farming are becoming widespread in the Lake Victoria basin. The tapping of the water reserves in wetlands may be considered as harnessing of water for production. In Uganda, for example, large expanses of floodplain wetlands in the mountainous southern districts have been converted into dairy farms. Cultivation of seasonal wetlands is even more widespread throughout the basin. Traditionally, these wetland zones were used for communal livestock grazing especially during the dry season. Dry season gardening is rapidly replacing communal grazing. Fish farming innovations, though still at very small scale and of limited spatial extent, are also being promoted along streams and in floodplain wetlands.

Dependence on water for production is high in the livestock keeping, drought prone zones of the basin such as the southeastern portion of Uganda. Flower growing is also highly dependent on water for production. The location of flower farms must be close to a permanent water source. Similarly, sugarcane plantations in areas with unreliable rainfall require a permanent source of water for irrigation. While dependence on water for production is still low, there is an increasing trend. In Uganda, the need is probably most urgent in the cattle corridor where water for livestock is increasingly limiting.

Pressures and environmental impacts on water for production

Several human pressures and environmental impacts associated with water for production have been identified. Provision of water for livestock using valley dams often leads to siltation of the dams, especially under communal nomadic regimes. Over abstraction of groundwater lowers water tables leading to drying up of springs, wells and boreholes. It could also disrupt plant/water relations. The dams attract water borne disease vectors and become infection centres for diseases like malaria and schistosomiasis. Contamination with other water borne diseases such as dysentery and diarrhoea could occur if the water is used for domestic use as well. The use of wetlands for agriculture as currently practiced in the Lake Victoria basin is unsustainable. It leads to extensive degradation of the buffering capacity of the wetlands and to subsequent loss of other environmentally valuable attributes of an entire biotope. This aspect will be discussed further with respect to human dependence and pressures on wetland ecosystems.

Dependence on Water for Municipal Sewage and Effluent Disposal

Water is vital for the treatment and disposal of municipal sewage and industrial effluents. Treatment plants are, therefore, always close to a permanent water source while municipal sewage and industrial effluent are often disposed of in aquatic ecosystems (wetland, river or lake). Suitability of water as medium for treatment and safe disposal of municipal sewage and industrial effluents is one of the factors that influence the location and growth of rural settlements as well as urban and industrial centres. The location and rapid growth of cities such as Kisumu, Kampala and Mwanza, towns such as Msoma, Homa Bay, and Jinja and numerous informal settlements along the shores of Lake Victoria is largely influenced by the reliable source of water in the lake for treatment and disposal of municipal sewage and industrial effluents. Similarly, dependence on permanent water source for sewage disposal is the main factor influencing the selective location of planned towns in the rural setting.

Human pressures and environmental impacts

Human pressures and environmental impacts associated with the use of water for treatment and disposal of municipal sewage and industrial effluent are proportional to the size of the population or industry to be serviced. These factors may influence completeness of the treatment and hence subsequent environmental impacts. Environmental pressures and impacts due to dumping of untreated or under-treated sewage and effluents into aquatic ecosystems include introduction of excessive nutrient loads into the ecosystem which may lead to eutrophication and anoxia, biodiversity loss and declining fisheries; and introduction of chemical pollutants such as heavy metals and/or BOD pollution.

Wetlands Ecosystems

Lake Victoria basin is endowed with a variety of extensive wetland ecosystems. Emergent, mostly permanent wetlands fringe the lakeshore and riverbanks; while the shallower inshore zones (often less than four meters deep) of Lake Victoria and much of the minor or satellite lakes constitute the inshore wetland zones (submerged or floating). These ecosystems are diverse biotopes of vital environmental and socio-economical importance.

The largest expanse of permanent and seasonal wetlands in Lake Victoria basin is associated with the floodplains of the inflowing rivers and streams. Floodplain wetlands often merge into the belt of fringing wetlands along riverbanks and portions of the lakeshore. Permanent wetland zones are usually dominated by *Cyperus spp* (sedges) especially *Cyperus papyrus.* Hippograss (*Vossia cuspidate)* and *Typha sp.* are the other commonly dominant emergent macrophytes. Temporary wetlands form a transition zone with dual characteristics of terrestrial and aquatic ecosystems. Small (minor) lakes, often less than four metres deep, occur within the floodplain wetlands. Those located close to Lake Victoria such as Nabugabo in Uganda and Kanyaboli in Kenya, are referred to as satellite lakes, possibly in reference to their proximity to the big lake. In this review, minor lakes are considered as part of wetland ecosystems.

The shallow inshore zone of Lake Victoria constitutes a special type of wetland, the inshore belt. This zone, which covers water often less than four meters deep, is characterized by submerged and floating aquatic water plants especially in bays with a muddy and/or sandy bottom (Balirwa 1998). The submerged water plants include *Ceratophyllum demersum*, *Potamogeton spp, Nymphaea spp, Trapa spp* and *Vallicineria spp*. The floating macrophytes are usually *Pistia stratiotes, Azolla spp, Lemna spp* and the introduced water hyacinth *Eichornia crassipes*. Water hyacinth in main Lake Victoria attained its largest extent between 1995 and 1999. The noxious weed was, however, brought under control throughout the lake by the year 2000. Water hyacinth remained prolific in River Kagera and in the delta zone of other rivers that drain into the lake (Twongo 2002). The weed is also still prolific in River Nile, the only outflow from Lake Victoria.

Stable wetland ecosystems of Lake Victoria basin are vital to environmental purity, biodiversity stability and biological productivity of entire aquatic systems they are often part of. Wetlands perform a variety of ecological functions, which are vital to the maintenance of water quality and availability; and to various biological processes. These functions include retention of sediments, excess nutrients and toxins; regulations of water flow, facilitation of groundwater recharge and discharge, biomass export and microclimate stabilization as well as carbon sequestration (Odada and others 2004). Wetlands, including those that fringe the inshore zones of Lake Victoria and the minor lakes, are havens for biodiversity and vital centres for a variety of biological processes. Inshore wetlands provide fish breeding centres, nurseries for young fish as well as food and shelter for most juvenile and some mature fish species. In summary, wetland ecosystems are fundamental to the ecological well-being and functioning of aquatic systems; inshore wetlands of Lake Victoria are crucial to inshore fisheries and to fish recruitment in the open lake.

Human dependence on wetlands ecosystems

Man derives a range of benefits from both the environmental attributes of wetland ecosystems as well as from socio-economic uses of the materials from the ecosystems. The filter capacity of wetlands for silt, nutrients, microbes and toxins is the basis for the use of wetlands in the final stages of municipal sewage treatment by the City of Kampala and the municipal authorities of Jinja and Masaka in Uganda. Socio-economic benefits of wetlands are derived from the use of wetland biomass and other materials including those used in building (clay for burnt bricks, sand and poles), thatching materials and a variety of other wetland biomass and materials for making mats and crafts. Wetlands are also a source of medicinal plants and fish. A rapidly growing use is the cultivation of seasonal wetlands to grow a variety of crops especially upland rice, cabbages, tomatoes sweet potatoes and maize during the dry season. Permanent wetlands with shallow water are extensively converted for agriculture including dairy farming. Planned wise use of wetland ecosystems and resources would generate sustainable environmental and socio-economic benefits.

Pressures and environmental impacts on wetlands ecosystems

Most aspects of utilization of wetland ecosystems and resources in the Lake Victoria basin are not based on proper planning. They often lead to serious ecosystem degradation and are, therefore, unsustainable. Intensive improperly planned excavation of sand and clay for construction occurs in wetlands especially those close to urban centres. In the process, valuable wetland biodiversity such as various palms (in Uganda) is destroyed. The large earth scarifications disfigure entire landscapes and trap water, where vectors for water borne diseases such as malaria and schistosomiasis thrive. The unplanned and non-regulated cultivation of seasonal wetlands and conversion of permanent wetlands with shallow water degrades these ecosystems at unsustainable rates. Wetlands that are used as disposal sites for partially treated sewage are liable to excessive loading with nutrients while the high rates of soil erosion due to poor land use expose wetlands to large sediment loads. The overall picture is that the wetland ecosystems of the Lake Victoria basin are getting degraded at unsustainable rates.

Human dependence on open lake ecosystem and affluent rivers

The open waters of Lake Victoria constitute a vast ecosystem rich in environmental and socio-economic resources. The estimated 2,760 km^3 volume of water in the lakes is the resource base for the ecosystem, the medium for aquatic biodiversity, biological productivity and for all the outputs of ecological processes including fisheries. Lake Victoria open waters constitute a large variety of potential socio-economic uses including domestic use, ecological production such as fish, hydropower generation, transport, tourism and recreation, industry and disposal of municipal and industrial waste. Most aspects of this potential are largely idle. Capture fisheries constitute the most important actively exploited biological resource of the lake. Biological resources such as shellfishes, which have proven potential as calcium supplement in the manufacture of poultry feeds, are barely exploited. Other aquatic resources in the Lake Victoria ecosystems include migratory and resident birds, large mammals (hippopotamus) and small mammals (Otta), as well as reptiles (crocodiles and monitor lizards) and amphibians. Birds are probably the most studied in this group of aquatic resources in Lake Victoria. For example 30 Important Bird Areas (IBA) have been designated in the Uganda portion of the lake while 70 were identified in Kenya. Birds in the IBAs are studied and monitored as part of a management process (Byaruhanga and others 2001). Few studies have been carried out on these taxa in spite of their importance in the food-chain and as biological indicators of ecosystem health in the land-water ecotones of Lake Victoria.

Biodiversity is one of the most fundamental of the ecological treasures of Lake Victoria. The full virgin scope of the ecosystem diversity of Lake Victoria will probably never be fully understood in view of the environmental degradation underway in the lake and the devastation by introduced predatory Nile perch. For example a massive decline in the diversity and abundance of haplochromines in the lake was demonstrated by the HEST (Haplochromine Survey Team) in Mwanza Gulf and linked to the establishment of the Nile perch in the gulf (Goldschmidt and others 1993; Witte and others 1992a, b). It is estimated that about 200 species of haplochromines in Lake Victoria were decimated through predation by Nile perch. The explosive speciation which led to the formation of such a large number of species is possibly the only indicator of the range of ecosystem diversity which existed in Lake Victoria. Similarly, while students of genetic diversity have the opportunity to study variability among the haplochromines using captive survivors in museums in Europe and North America, many species which occurred in Lake Victoria would have been lost. On the other hand, open water biodiversity with respect to macro invertebrates, algae as well as micro fauna and flora of the open lake have registered relatively little studies beyond taxonomic identification of invertebrates and algae. Interpretation of human dependence on biodiversity of the open waters of the lake is, therefore, limited to the vital role the resource plays in the ecological dynamics of biological production (including fishery production) and water quality maintenance.

The traditional fish fauna and fishery of Lake Victoria was dominated by Cichlids (Graham 1929; Greenwood 1966;). Two Tilapia species (*Oreochromis esculentus* and *Oreochromis variabilis*) plus a few other fishes (*Bagrus docmac*, and *Labeo victorianus*) were the mainstay of the commercial fishery, while, haplochromines, which evolved in the lake into about 300 species through explosive speciation, dominated the itchthyofauna. Many of the haplochromine species were endemic to Lake Victoria. The fishery was a major source of revenue, protein and employment opportunities especially for the lakeside communities. Alien fish species including the Nile tilapia (*Oreochromis niloticus)* and predatory Nile perch (*Lates niloticus*) were introduced into the lake in the 1950s and 1960s. The predator was expected to convert the haplochromine cichlids to more commercially viable Nile perch. Establishment of the two introduced species, however, led to severe decline of the indigenous commercial species culminating in a three species commercial fishery dominated by the three aliens and the indigenous cyprinid (*Rastrineobola argentia*).

Pressures and environmental impacts on open lake ecosystem and affluent rivers

The major human induced pressures on the open waters of Lake Victoria and the affluent rivers include siltation, nutrient loading, introduction of chemical pollutants, proliferation of alien introduced species especially the water hyacinth and Nile perch, and excessive fishing pressure combined with the use of destructive fishing gears and methods.

Pressures on open lake ecosystem and affluent rivers

Affluent rivers are the major point source conduits of silt into Lake Victoria. The serious soil degradation underway in most of the lake basin due mainly to poor land use practices and the degradation of wetland buffers is most vividly revealed by the silt-laden inflows of these rivers. Non-point entry of silt into the lake also occurs especially where wetland and other vegetation buffers are degraded. Sustained inflow of sediments rich in nutrients into Lake Victoria through rivers draining farmlands of western Kenya are suspected to contribute to the eutrophication in Nyanza Gulf (COWI 2002). The main sources of phosphorus, which fuels the serious eutrophication in parts of Lake Victoria has been, however, attributed to atmospheric deposition as dry and wet fall onto the lake surface, as well as to under treated and untreated municipal sewage and industrial effluent from the numerous population centres around the lake (COWI 2002; Mott MacDonald and others 2001). Chemical pollutants entering the lake include heavy metals, and improperly treated or untreated industrial effluents such as that from paper mills, leather tanneries and gold mines (NEMA 1997). Heavy siltation and sedimentation in rivers and the lake impair benthic flora and fauna while excessive nutrient loads of phosphorus and nitrogen fuel eutrophication and the subsequent anoxia in parts of Lake Victoria.

Growth of the Nile perch fishery in Lake Victoria was rightly hailed as a positive socio-economic development. The resultant fishery returned much higher catches and the predator was the major contributor to the lake fishery estimated at 500,000 metric tons annually (FIRRI 2002). Nile perch became a vital foreign exchange earner for the riparian states of Lake Victoria. Rapid increase in fishing effort and widespread use of destructive illegal fishing gears and methods (undersize gillnets, seine nets and castnets) over the last thirty years exerted considerable pressure on the fish stocks of Lake Victoria. For example, fishing effort in the Ugandan portion of the lake increased from about 3000 canoes in the 1970s to about 15,000 by the year 2000 (FIRRI 2002). The negative environmental impacts attributed to the alien introduction, however, do stand out. They include the decimation of a spectacular endemic species flock of haplochromines, whose trophic diversity (phytoplanktivores, detritivores, zooplanktivores, insectivores, molluscivores, piscivores and egg-eaters) contributed to high trophic efficiency and ecological balance in Lake Victoria. It is thought that perhaps the subsequent absence of the haplochromine algal grazers in the lake exacerbated the accumulation of phytobiomass, the causative increase due to nutrient enrichment not withstanding. The intense decomposition of the phytobiomass causes serious oxygen deficits in nearshore bays and gulfs such as Murchison, Napoleon, Winam and Mwanza, which are some of the most productive zones of Lake Victoria. Competitive displacement of other fishes especially the native predators (*B. docmac, C. gariepinus, B altianalis, P. aethiopicus*) from the lake by Nile perch would have upset the ecological efficiency of the ecosystem even more. It is, therefore, difficult to predict the ecological/evolutionary sustainability of the three species' (Nile tilapia, Nile perch, dagaa) commercial fishery of Lake Victoria.

Water hyacinth was first reported in Lake Victoria at the close of the 1980s (Twongo and others 1995). Proliferation and spread of the weed was highest in sheltered nutrient-rich bays. The highest areal cover of water hyacinth reported in Uganda was about 4000 ha in 1998 (Twongo 2002); in Kenya and Tanzania the highest reported were 6000 ha and 2000 ha, respectively (EAC 1999). Water hyacinth was brought under control in Lake Victoria between 1998 and 2000 by biological control using weevils (*Neochetina spp*), ecological succession and selective manual and mechanical removal (Twongo 2002). Water hyacinth was, however, not controlled in the affluent rivers especially the Kagera and the Mara. Subsequent resurgence of water hyacinth in the Lake Victoria has so far been limited to the highly enriched sectors of the lake such as the inner portion of Murchison Bay in Uganda. Proliferation and spread beyond these centres was contained mainly by the effects of biological control using weevils, which quickly multiplied and became re-established. Proliferation of water hyacinth had considerable impacts on ecology and socio-economic interests in Lake Victoria.

Environmental impacts on open lake ecosystem and affluent rivers

Pressures due to human induced siltation, nutrient loading, chemical pollutants, alien species and unsustainable fishing induce a variety of corresponding impacts on the open lake ecosystems of Lake

Victoria, and in the affluent rivers. It is, however, expected that heavy siltation of the water column is likely to restrict gaseous exchange of aquatic animals such as fishes, which extract dissolved oxygen from the water. It would also limit light penetration and hence lead to reduced primary productivity. The resultant sedimentation would impair benthic flora and fauna. Lake Victoria ecosystems have been under the threat of eutrophication since the early 1990s when changes in oxygen regimes and phytoplankton composition were noted (Hecky 1993; Mugidde 1993; Lehman and Branstrator 1994; Ochumba 1996). Comparisons with earlier data collected by Talling, (1965) and Talling (1966) demonstrate serious eutrophication trends in the inshore waters of Napoleon Gulf, Winam Gulf and the open waters near Bugaia Island. A recent (2000 and 2001) lake-wide water quality/limnology study by Lake Victoria Environment Management Programme (LVEMP) also showed presence of significant levels of eutrophication in the above gulfs, the region near Bugaia Island, and other near-shore zones of Lake Victoria (COWI 2002). The spatial spread of eutrophication did not, however, extend over most of the deep open lake. On the other hand, Cyanophyceae, the most prolific types of algae in eutrophic environments, were the dominant phytoplankton taxa lake-wide (COWI 2002). The implications of this finding need to be established urgently. Some species of Cyanobacteria produce phycotoxins. Pronounced but localized eutrophication of near-shore waters of Lake Victoria in Uganda was identified and linked to nutrients generated at heavily populated landing beaches (Mott MacDonald and others 2001). The observed eutrophication of Lake Victoria and the associated hypoxia in the deeper zones of the affected water column constitute the cumulative environmental impacts due to the human induced nutrient loading of the lake.

Although proliferation of water hyacinth in Lake Victoria had a few positive attributes, on balance, the invasive weed was undesirable. Narrow fringes of well-oxygenated water hyacinth formed useful refugia for various biodiversity including small and young fish. Several types of adult fish fed in this weed belt (Willoughby and others 1993; Balirwa 1998). Fish species especially the lungfish and mudfish, which tolerate low oxygen levels, flourished in water hyacinth mats close to the more oxygenated zones. The habitat became particularly suitable for lungfish and mudfish when the succession with hippograss climaxed. The negative impacts due to the infestation, however, outweighed the above advantages by far. Water hyacinth inflicted detrimental impacts on the environment and socio-economic interests in Lake Victoria. The infestation disrupted socio-economic activities especially fishing, water transport, hydro-electricity generation and water abstraction and hiked treatment costs. Infestation by resident water hyacinth mats along the shoreline seriously degraded near-shore wetlands. Macrophytes were smothered or shaded out together with the nurseries and feeding grounds of various fishes. Biodiversity was displaced due to anoxia and poisonous gases such as ammonia and hydrogen sulphide in the anoxic environment under the resident water hyacinth mats (Wanda and others 2001). Considering the estimated total weed cover of 12,000 ha (EAC 1999) and the highly migratory nature of the weed, the total environmental and socio-economic cost was huge.

Impacts due to excessive fishing effort include decline in the average size of fish captured and eventual reduction of the brood stock far below optimum levels. Intense use of under-size gear would eventually affect recruitment of juvenile fish into the fishery. Destructive gears such as beach seines destroy fish breeding grounds and nursery beds if used indiscriminately. The full impacts of unsustainable fishing pressure and methods take time to build up and they may require drastic measures such as closing the fishery for some time, to remedy.

HUMAN VULNERABILITY AND COPING STRATEGIES

In the previous section, the environmental impacts generated by human pressures due to man's socio-economic dependence on a range of freshwater related aspects, were identified. This section discusses issues of human vulnerability and coping strategies in relation to those environmental impacts. The freshwater related issues considered thus far are rainfall, water for domestic use, water for production, wetland ecosystems, open lake ecosystems and affluent rivers. Cases of human vulnerability and available coping strategies have been identified against the environmental impacts generated for each issue. Coping strategies considered include policy initiatives, institutional frameworks, as well as relevant programs in the Lake Victoria basin.

Summary of human vulnerability and coping strategies

Human vulnerabilities and coping strategies are summarized below against the impacts generated for each freshwater related aspect.

Rainfall

Spatial and temporal variability in quantity and reliability of rainfall in the Lake Victoria basin is considered to be associated with potentially serious environmental impacts including devastation of agriculture. Cases of human vulnerability in the basin, related to these impacts include inadequate capacity to forecast and assess rainfall; inability to control rampant degradation of catchment forests, which contributes to rainfall variability; the almost total dependence on rain-fed agriculture; and lack of capacity to substantially harness the irrigation potential in the lake basin as a coping strategy. Some coping strategies already adopted by the basin states include: relevant policies and institutional arrangements; existence of rainfall monitoring networks; and some highly trained staff. The existing rainfall monitoring networks and professional staff are, however, inadequate.

The second set of environmental impacts relate to increased extreme flood and drought events in the basin. Human vulnerability to the impacts is due to inadequacy of early warning mechanisms in the basin such as: predictive databases; inability to control degradation of natural flood buffers like catchment forests and wetlands; and lack of preparedness to mitigate flooding. Elements of coping strategies are indicated by the presence of sectoral policies such as those that guide management of forestry, agriculture, wetlands and water resources in all the basin states. National Environment Management Authorities (NEMA), mandated to coordinate, monitor and oversee sustainable natural resources management, are in place in Uganda and Kenya and in advance stages of formation in Tanzania. The capacity of the sectoral institutions to provide early warning information on floods and drought and that of the NEMAs is, however, still inadequate.

Domestic water supply

Serious environmental impacts are caused by dropping water tables due to drought or excessive abstraction of water, which leads to drying of water sources such as wells, boreholes, streams and wetlands. Human vulnerability to these impacts is illustrated by the inevitability of trekking long distances in search of water and the inability to tap more reliable distant or underground water sources due to financial and technical constraints. Other impacts relate to contamination of domestic water supply (surface and underground) with pathogens, debris, odour through unsustainable land use practices, and poor sanitation and hygiene. Natural contamination of groundwater with excessive salt content is also well known. Rural and some urban communities often have to put up with unsafe water due to inability to afford safe alternative water sources or due to widespread poor sanitation and hygiene. Endemic exposure to water borne diseases usually due to lack of preventive and curative initiatives entrenches their prevalence in the communities with considerable toll on human productivity. Basic coping strategies to the above impacts include: policies and institutional arrangements towards provision of safe water in place in all member states of the Lake Victoria basin; efforts to implement relevant Millennium Development Goals (MDGs); and the relatively good but partial coverage of safe water in urban centres and some rural population centres. On the whole, rural communities dependent on surface water (rivers, streams and unprotected springs) are generally exposed to contaminated water. Increased supply of groundwater to rural communities would improve domestic water quality and availability.

Water for production

Dropping water tables in boreholes and water level in lakes, river, streams and wetlands due to drought and or unsustainable water abstraction are serious common environmental impacts in Lake Victoria basin with devastating consequences to various aspects of production including livestock husbandry, irrigation and wildlife management. In drought prone areas with communal valley dams for livestock, siltation is a major environmental problem. Human vulnerability to these impacts is reflected by: the often inadequate available capacity to assess, monitor and develop groundwater resources to enable equitable allocations; absence of reliable data on requirements of water for production; dependence on

groundwater for production as well as for domestic use, which accelerates unsustainable abstraction especially in drought-prone areas; and the inability to develop irrigation infrastructure where the potential based on surface water is good. A related environmental impact to the use of valley dams to store water for livestock is the likely infestation of the dams with disease vectors such as for malaria and bilharzias, and pathogens for dysentery. A variety of vector control strategies such as introduction of fish (e.g. the guppies) to check breeding of malaria transmitting mosquitoes are possible coping strategies.

Wetland degradation in search of water for production is increasing rapidly in the basin. The urge for dry season gardening, accelerated by population pressure and poverty, exacerbates the degradation of wetlands by rural communities. Similarly, lack of relevant irrigation strategies partly fuels the increased conversion of wetlands for intensive agriculture. Although wetland policy guidelines and strategies are in place in Uganda and Kenya for example, specific institutional arrangements and proven guidelines for sustainable use of wetlands in agriculture are inadequately developed or lacking altogether. An urgent need exists, in this area if sustainable management of temporary wetlands and permanent ones with shallow water reservoirs is to be achieved.

Water for municipal sewage and industrial effluent disposal

Treatment of municipal sewage and industrial effluents may be done using surface or groundwater. Eflluents are, however, often disposed of through channelling into surface water. Environmental impacts associated with the effluent disposal into Lake Victoria include: biodiversity degradation due to eutrophication and anoxia caused by excessive nutrients from sewage; localized reduced fish production due to environmental degradation and decline of suitable food species; and insufficiently treated industrial effluents. Human vulnerability may result from lack of inability to afford alternative safe water, lost livelihood by lakeside communities in case of disrupted fishery production, and water users having to foot the increased water treatment costs. Available coping strategies include water quality management policies and compliance with effluent treatment standards. Institutional arrangements for water quality management in Uganda, for example, are vested in sectoral institutions such as NWSC and departments like DWD (the lead agency). NEMA has the oversight and supervisory mandate but comprehensive strategies for coordination and monitoring for compliance are, however, inadequately developed.

Wetlands ecosystems

Wetland ecosystems in Lake Victoria basin are under immense pressure from the rural communities through intense agriculture, as well as from urban and industrial developers. Major environmental impacts due to that pressure include: loss of buffering capacity (for silt, nutrients, toxins, floods); degradation and eventual loss of wetland biodiversity, and loss of potential for groundwater recharge or discharge and macroclimate stabilization due to unplanned large scale drainage conversion for agriculture, urban development or industry. Another form of environmental impact entails destruction of biodiversity and aesthetic value, and creation of water pools through indiscriminate excavation of sand and clay. The pressures also lead to: loss of traditional socio-economic benefits including water, and biomass harvesting for various purposes such as building materials, thatch, handcraft making materials and medicines; as well as fishing, hunting, dry season pasture and communal firewood gathering. Human vulnerability to the perpetuation of these impacts appears to be due to population pressure and poverty, undeveloped irrigation to provide an alternative for intensive all-seasons agriculture, insufficient sensitization on values of wetlands in relation to long term cost of ongoing wetland destruction, and politically instigated pressures and interference. Local communities are particularly vulnerable because once a wetland is destroyed restoration may be very difficult and prohibitively expensive. In any case, restoration to the original socio-economic benefits and environmental values would be unlikely.

Some coping strategies towards wise use are, however, available. They include strategies and institutional arrangements to control siltation, one of the key elements in the degradation of wetland ecosystems. These are embedded in various sectoral land use policies such as in forestry, crop production, livestock and wildlife management, and urban development. Unfortunately, coordination and consolidation of the outputs from the policy strategies towards effective management of soil erosion remains difficult.

Wetland policies are in place, for instance, in Uganda and Kenya, but specific institutional arrangements and legal instruments to guide sustainable use of wetlands for agriculture are inadequately developed or lacking. Clearly the coping strategies need revitalization or rethinking to be effective against the rampant degradation of wetland ecosystems in Lake Victoria basin.

Open lake ecosystem and affluent rivers

Lake Victoria is the main open lake ecosystem in the basin. Most of the minor-lake ecosystems were considered under wetland ecosystems. The environmental impacts, instances of human vulnerability and the coping strategies discussed below refer to Lake Victoria.

Eutrophication

Eutrophication leading to hypoxia is one of the most far-reaching impacts on Lake Victoria ecosystems. The main pressure leading to eutrophication in the lake is nutrient loading from land use, atmospheric deposition, and from municipal sewage and industrial effluents. Eutrophication and hypoxia lead to: degraded habitats; reduced habitable space for aerobic species; reduced productivity, for example, of the fishery; and to degradation of biodiversity in general. Algal blooms that characterize the eutrophication in Lake Victoria are usually poisonous producing cyanobacteria. Lake Victoria is the primary source of water for the cities and towns along its banks, the presence of algal blooms increases the cost of water treatment for domestic supply. Human vulnerability associated with the above impacts may be portrayed through the inability to control nutrient sources especially due to poor land use practices and atmospheric deposition. Other instances of vulnerability are the frequent dependence on contaminated lake water by the rural communities due to either lack of alternative water sources or the prohibitive cost of treated water.

Several coping strategies towards control of nutrient enrichment of the lake are in place. All riparian states have provisions aimed at proper management of nutrient sources in their national sectoral policies and institutional arrangements. Sectoral management effort is, however, basically inadequate and needs strengthening. The Treaty for the establishment of the EAC provides vital general principles on regional obligations to towards sustainable management of natural resources. The Protocol for Sustainable Development of Lake Victoria Basin, signed by the riparian states but yet to be ratified, sets a more specific and regionally binding agenda. Operationalization of this protocol would be vital while dealing with the international aspects of the problem. On the other hand, admission of Rwanda and Burundi to the EAC remains a condition to basin-wide compliance with the management guidelines.

Introduced alien species

Human vulnerabilities associated with alien species introductions into Lake Victoria included lack of options to influence the natural ecological dynamics due to the introductions in a large water body like Lake Victoria. Secondly, human socioeconomic interests were totally subjected to the disruptive dynamics of the water hyacinth mats until control was affected. On the other hand, the fisher community appears to have become so vulnerable to the loss in livelihoods that when fish concentrations were identified in the shoreline strips of the weed, many of the beneficiaries failed to consider the overall impacts of water hyacinth proliferation and claimed that water hyacinth proliferation after all enhanced fish production. The spatial extent of the new fishery was comparatively minimal and lasted only until the shoreline strip of macrophytes was-depleted by the fishers or drifted off. Two aspects illustrate the coping strategies to the proliferation of water hyacinth. Existing sectoral institutional arrangements and departmental mandates were used to develop strategies to control water hyacinth in Lake Victoria. Regional coordination was achieved through FAO and LVEMP and the regional funding was through LVEMP. Physical weed control emerged as a practical relief measure and regional consensus was reached on use of two *Neochetina* weevil species for biological control on shared Lake Victoria; While the strategies have so far kept weed infestations on Lake Victoria under control, active proliferation still occurs on River Kagera and the lower reaches of several affluent rivers including River Mara. Improved or new coping strategies are required for those riverine environments. The second aspect illustrates the coping abilities of the fisher community. Fisher communities have been quick to discover and harvest

the stocks of fish in the narrow stationary water hyacinth. The fish harvest often involves destruction of the new habitats and is, thus, unsustainable.

Unsustainable fishing pressure

Excessive fishing effort combined with use of undersize gillnets and other destructive gears and methods enhanced brood stock depletion. A direct impact is the increase in the proportion of immature fish landings, declining size at maturity and declining average catch per canoe. A major human vulnerability is that population pressure plus lack of alternative livelihoods encourage continued entry into Lake Victoria by new fishers to join traditional fishers, who have to continue fishing to survive. An open access fishery regime and lack of stakeholder ownership of the resource constrain self-restraint. At transboundary level, insufficient mobilization and sensitization especially across national borders hinders development of unity of purpose towards adoption and implementation of sustainable fishing practices among fisher communities. Available coping strategies include revitalized fisheries policies to clearly stipulate strategies for sustainable fisheries resource utilization and preservation of the fisheries resource base, with active stakeholder participation for example in Uganda. Intensive regional dialogue and planning under the coordination of LVFO and funding through the Integrated Fisheries Management Project (IFMP) are underway. Supporting institutional arrangements are in place but the legal aspects are in need of updating and strengthening to match new policy objectives and strategies. Funding mechanisms for monitoring, research, information dissemination need strengthening.

CONCLUSIONS AND RECOMMENDATIONS

A review of human dependence, the resultant pressures and subsequently human induced environmental impacts on five freshwater related aspects (rainfall, water for domestic use, water for production, wetland ecosystems, open lake ecosystems and affluent rivers) in the Lake Victoria basin over the past thirty years has been addressed in this paper. Human dependence and vulnerability to the freshwater related aspects for socio-economic wellbeing and development have also been discussed and coping strategies identified. The people of the Lake Victoria basin are vulnerable to spatial and temporal variability in quantity and reliability of rainfall because available coping strategies such as capacity to forecast and monitor rainfall, capacity to harness water for irrigation, ability to manage catchment forests sustainably, and inadequate or lack of early warning mechanisms for floods and droughts.

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Land cover, land use change and related issues in the Lake Victoria basin: States, drivers, future trends and impacts on environment and human livelihoods

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ABSTRACT

Land is a critical resource for the survival of the over 25 million inhabitants of the Lake Victoria basin in which agriculture contributes immensely to local and national economies. The steady decline in per capital land holding and escalating land degradation are posing serious concerns to food security and environmental integrity thus threatening economic, social and physical survival in the lake region now and in the future. The key land degradation issues addressed in this paper include escalating soil erosion, declining soil fertility, agro-chemical pollution, salinization and loss of land cover. Using the following driving force framework, that is, pressures-states-impact-response (DPSIR), the paper presents a synthesis of the state of land use and land degradation in the basin, their causes and impacts on human and environmental security. The paper notes that protecting the land quality for the benefit of people is a major challenge in the basin and that the dilemma in sustainable land management in the basin is that land use changes needed to promote the survival of society in the long-term are at crossroads with what is essential to the survival of the population in the short-term. An analysis of future scenarios of the Lake Victoria land resources and land use change is presented based on plausible futures through long-term interactions between economic development and environment with a reflection on the future state of available arable land in 2025. The social, biophysical and institutional mitigations measures proposed are based on these interactions.

Keywords: *Integrated water resources management, Lake Victoria basin, land use, land cover, land degradation, scenario, sustainable land management, wetlands*

INTRODUCTION

Lake Victoria basin is located in the upper reaches of the Nile River Basin and occupies an area of about 251,000 km^2 of which 46% is in Tanzania (URT 1995). Kenya, Uganda, Rwanda and Burundi share the remainder of the area. The basin contains Lake Victoria, which is the largest freshwater lake in Africa and the second largest lake of the world. Lake Victoria has three riparian countries, namely, Kenya, Uganda and Tanzania, and draws its water from direct rainfall as well as from several rivers such as the Kagera, Mara, Simiyu, Gurumeti, Nyando, Migori and Sondu-Miriu. Its catchment area is surrounded by mountains on all sides except for the north (Figure 1). The average population density in the basin is 165 persons/km^2.

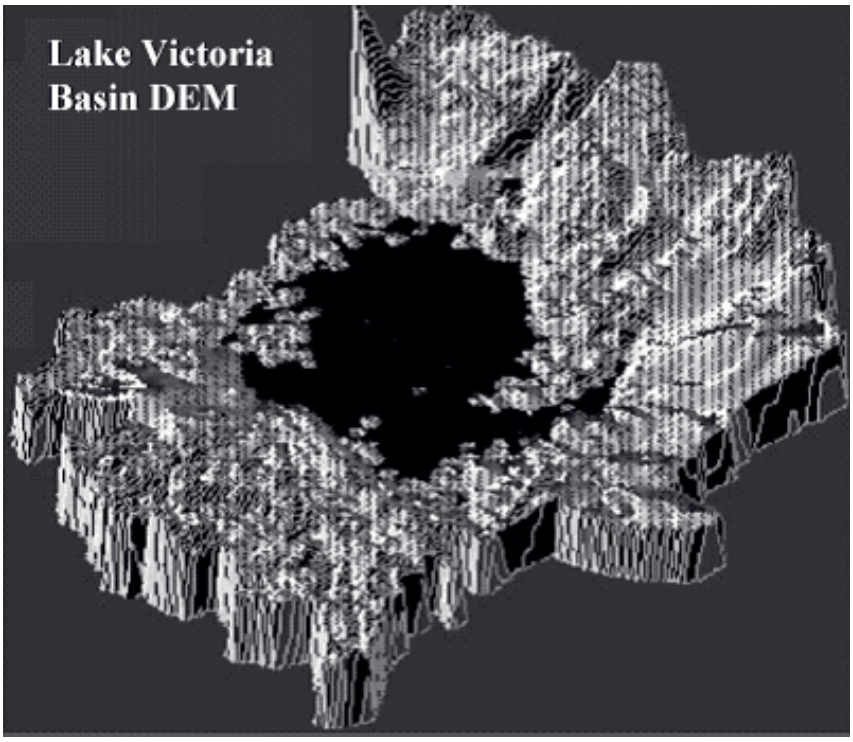

Figure 1: A digital elevation model DEM) of Lake Victoria basin

Source: FAO (2002).

Land is a critical resource for the survival of the over 25 million inhabitants of the Lake Victoria basin. In all the riparian countries, agriculture contributes over 30% of the GDP and employs close to 60% of the labour force (World Bank 1998). There has also been witnessed a steady decline in the size of per household land holding in the decades leading to 2004 (Figure 2). This coupled with the basin's population growth rate of about 3% per year underscores the need to slow down the rate of land degradation. It is estimated that the availability of agricultural land *per capita* will fall from the current 0.75 ha to a paltry 0.35 ha in 2025. Growth in the agriculture sector should be accelerated at a rate of over 8% in real terms by the year 2025 and beyond. It will be inconceivable for the region to achieve this growth target without sustainable land management efforts.

The continuous decline of per household land size and cultivated land per person constitute threats to food security, especially where rural populations depend on local land resources for their livelihoods. Land resources in the Lake Victoria basin present the inhabitants and their development partners with monumental paradoxes including:

- ❑ Enormous natural resource wealth with potentially high endowment value yet majority of the people live in abject poverty;
- ❑ It is the home of incredible land use diversity yet the ecosystems are fragile and easily degraded by unsustainable land use.

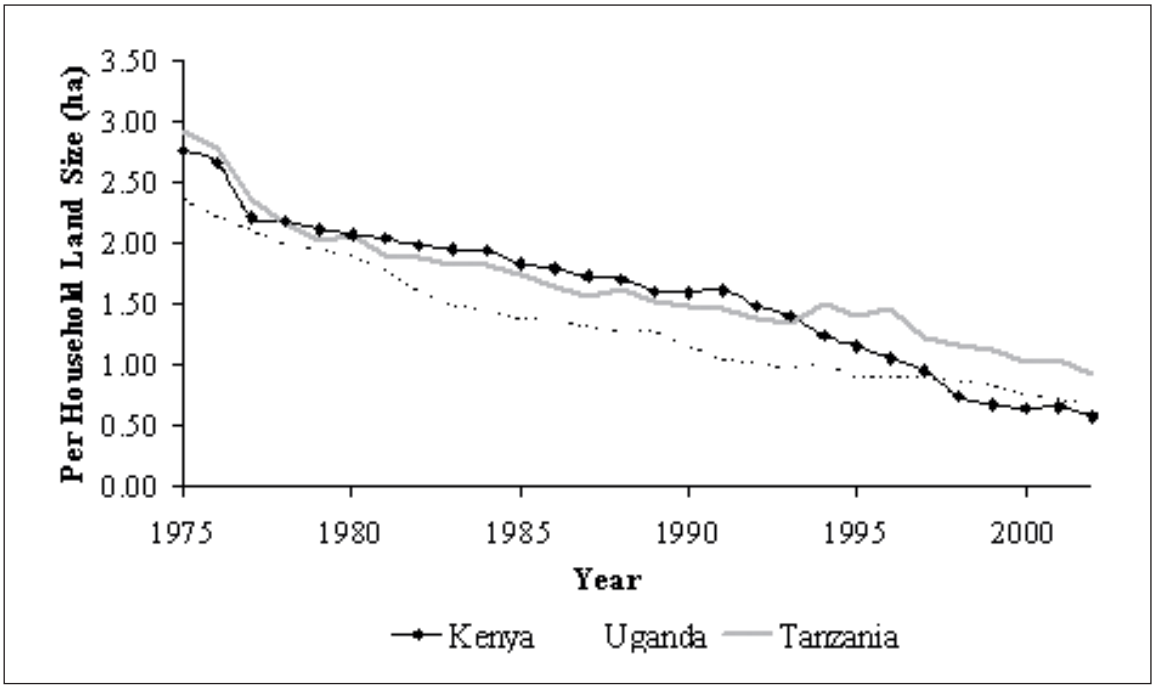

Figure 2: *Per capita* land holding of countries in the Lake Victoria basin.

Like in many other parts of sub-Saharan Africa, land degradation is threatening economic, social and physical survival in the lake region. The key land degradation issues include escalating soil erosion, declining soil fertility, agro-chemical pollution, salinization and loss of land cover. There also exists incremental wetland loss occasioned by natural hazards and intensification of land use as well as other malign anthropogenic activities. The continued poverty of the majority of the inhabitants of the Lake Victoria region is linked to the continued land degradation. The present land use and environmental courses of action are largely unsustainable and no longer constitute options to a sustainable future.

LAND USE

Land use in Lake Victoria basin has been characterised by two-riding trends over the past three decades. First, the land resources are greatly threatened by grave imbalances in productivity and environmental integrity. This worsens the state of food security and integrity of the environment, which in turn threaten the stability of societies and the regional environment. Secondly, the region is undergoing accelerated change, with land stewardship lagging behind economic and social development. Land productivity is being overtaken by population growth. The processes of social and economic development need to be directed towards resolving rather than aggravating land resource issues and concerns. Box 1 presents some statistics pertaining to land use and land issues in the basin.

Box 1: Some statistics ...

- Average regional *per capita* land holding is about 0.75 ha.
- Average regional *per capita* income is under 250 US$
- Population increases at an annual rate of 3%
- The efforts needed to meet land use needs for the additional 5 million people in the next 30 years will be immense.
- A two-fold reduction of degraded land is necessary in the next 20 years for the growing needs of the inhabitants.
- An estimated 150, 000 km² of land has been affected by soil degradation since 1980 including as much as 60% of agricultural land.
- About 75% of wetland area has been significantly affected by human activities and about 13% is severely degraded.

LAND DEGRADATION

Over the past three decades, intensified cultivation of marginal areas and clearance of natural habitats like wetlands, forests and mountainous areas have been witnessed. These have been the main driving forces behind the escalating land degradation in region. The forces are so intense that many wetlands such as Nakivubo Wetland in Uganda and Yala Swamp in Kenya are heavily degraded (Abila 2002).

The Nakivubo Urban wetland is held in trust by the government, but the surrounding lands are privately owned. This has led to confusion about the boundaries, ownership and status of the wetland. Approximately 100,000 people reside in the wetland. Due to its close proximity to Kampala, the capital city of Uganda, the wetland is an important sink for domestic and industrial discharge from three main sources (Nakivubo Channel; Bugolobi sewage treatment works; and run-off, seepage and point sources from households and adjacent farmlands). The major threat to the agro-ecosystems health and integrity of Nakivubo Urban wetland is reclamation for agricultural, industrial and residential expansion. About half of the total area (5.29 km²) has been modified or reclaimed for agriculture, industry and settlement and there is eminent threat of complete loss of the entire wetland through modification and conversion into urban uses. The degradation process is exacerbated by unsustainable exploitation of the wetland resources such as crop cultivation, papyrus harvesting and brick making.

The Yala swamp is one of the few extensive wetlands found in western Kenya. The wetland covers an area of 17,500 ha and contains three freshwater lakes, Kanyaboli, Sare and Namboyo (LBDA 1989). The swamp vegetation comprises mainly of papyrus (*Cyperus papyrus*) and *Phragmites* reeds. This wetland is nationally important in that it is one of the few habitats where the threatened Sitatunga antelope (*Tragelaphus spekeii*) is found in Kenya. The wetland is important for biodiversity, but also has great socio-economic value to the local communities, for whom the wetland has long been a source of fish, vegetables, medicinal plants, building materials, and agricultural land. Since the wetland is not protected, it is vulnerable to overexploitation. There are conflicts over issues with regard to its utilization – community-based resource management, agro-industrial development, or biodiversity conservation. The wetland can be sustainably utilized without undue degradation through its exploitation by the papyrus industry, brick making, aquaculture, ecotourism and energy extraction. Unlike other wetlands in Kenya, the Yala swamp does not have a protected status, therefore uncontrolled exploitation of the wetland and its resources can take place. It has been subject to reclamation since the 1960s, mostly for agricultural purposes, such as the growing of rice, groundnuts, cassava, yams and sugarcane. The threats to the wetland are twofold: population growth that drives the unsustainable use of the wetland's resources; and government initiatives on reclamation of the wetland for agricultural purposes.

The incremental loss of natural habitats has reduced vegetation cover exposing soils to both wind and water erosion, further worsening the degradation problem. Water erosion is extensive in many parts of Lake Victoria basin with approximately 45 percent of the land prone to water erosion (Reich and others 2001) and riverbanks are destroyed by gulley erosion (Plate 1). Siltation of dams and the increased risk of flooding in rivers and estuaries are the direct effects of soil erosion and other degradation forces in the basin. The near annual flash floods in Budalangi and Kano plains have been linked to such forces emanating from point and non-point processes (Gichuki 2003).

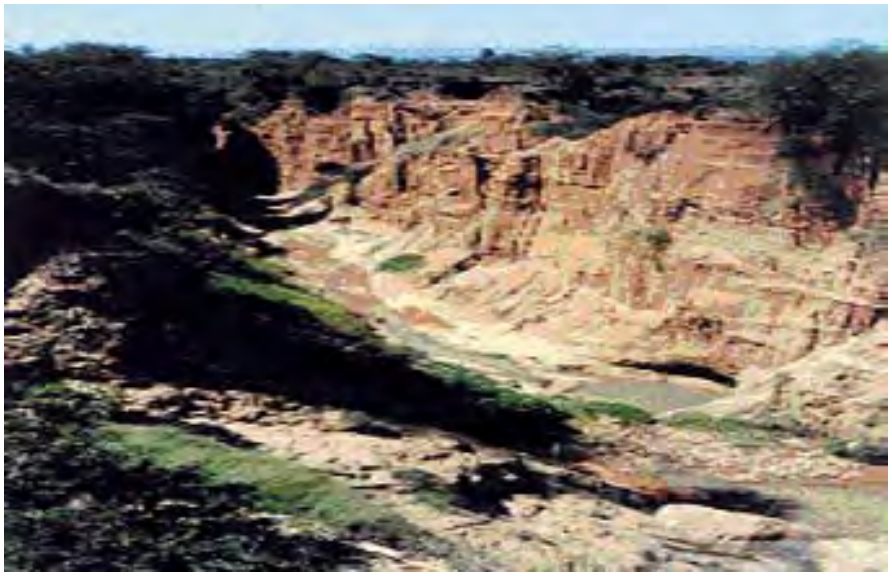

Plate 1: Gullies causing destruction of the banks of a seasonal tributary of River Nyando.

Source: van der Kwast (2002).

Owing to the realization that the Lake Victoria basin is endowed with largely untapped resources and that there is a potential threat posed by these degradative forces, the East African Community (EAC) and other development partners like the Governments of Sweden, France and Norway, the World Bank and the East African Development Bank (EADB) have entered into a long-term partnership on the promotion of sustainable development of the basin. This was in response to the realization that the potential of the basin cannot be sustainably developed unless problems related to environmental degradation, deepening poverty and poor health standards are addressed in a broad and coordinated manner. The partnerships have seen the institutionalization of intergovernmental and international arrangements that largely focus on activities related to the sustainable development in the region including: the Lake Victoria Environment Management Project (LVEMP); the Nile Basin Initiative (NBI) and its sub-affiliate, the Nile Equatorial Lakes Subsidiary Action Program (NELSAP); the Lake Victoria Fisheries Organization (LVFO); the Lake Victoria Region Local Authorities Cooperation (LVRLAC); the Inter-University Council of East Africa; and ECOVIC, a consortium of Community-Based Organizations and Non-Governmental Organizations in the basin.

Hitherto, land use policies have not adequately addressed the root causes of land degradation. The recent trends in land degradation can be linked to imbalances in land distribution, lack of incentives for conservation, insecure tenure and the failure to provide for diversified rural production systems (Moyo 1998). The United Nations Convention to Combat Desertification (UNCCD) asserts that land degradation is intricately linked to poverty and that addressing this problem requires the participation of the resource users and, where appropriate, providing them with alternative livelihood options (UNCCD 2001). Jones (2002) presents a framework grounded on the “sustainable livelihoods” approach that generates a clear understanding of the social causes of environmental degradation and factors that affect land use decision-making. The “sustainable livelihoods” approach advanced by Scoones (1998) has three inherent dimensions (Birch-Thomson, and others 2001): how wider socio-economic and socio-political change relate to local changes; emphasis on importance of social differentiation and agency in determining outcomes of local change; and the importance lent to both physical and social resources employed in shaping livelihood strategies. The approach resonates well with the driving forces (pressures – states – impacts – response (DPSIR)) and opportunities frameworks which are used in presenting the state, trends, indicators and opportunities for sustainable land management in this review.

The Lake Victoria basin states have signed and ratified several regional and international conventions. Although this has served to enlist government commitment and raise public awareness about issues of sustainable natural resource management, the resources required to enforce these plans have frequently been inadequate (UNCCD 2001). Studies have estimated that land degradation processes affect up to 60 percent of the basin's land area (Figure 3). The areas adjoining the shores of the lake are at greatest risk of degradation with about 65 percent facing high or very high risk of degradation (UNEP 2002a). Degradation vulnerability in Lake Victoria basin is severe with 46 percent of the area at risk, of which 55 percent is at high or very high risk (Reich and others 2001).

Sustainable land management initiatives and programmes are closely linked to socio-economic conditions and other factors, which determine their success. SARIPS (2000) identifies improvement in wealth distribution, access to resources and economic opportunities as key factors. The benefits of improved land management, or the negative consequences of land use practices on water resources, might not only be felt by resource users who cause them, but also by others who live downstream or make use of the affected resources.

The land degradation problems facing the Lake Victoria basin are multi-faceted. The country specific extent of land degradation is shown in Figure 3. The factors are several and include both natural and human-induced driving forces (Figure 4). The effects of these factors have been exacerbated by the consequences of decisions and policies as well as cultural, social and economic circumstances. These factors over the years, especially within the last twenty, have considerably changed the basin's ecosystems and this in turn rendered the population dependant on its vast natural resources vulnerable and insecure in terms of poverty, food security and health. The transboundary characteristics of the lake basin present it with unique opportunities and challenges in the attempts to address land related issues. Decisive and appropriate actions that take into account these facets can significantly reduce vulnerability and increase human security through programmes that strengthen coping capacities at all levels.

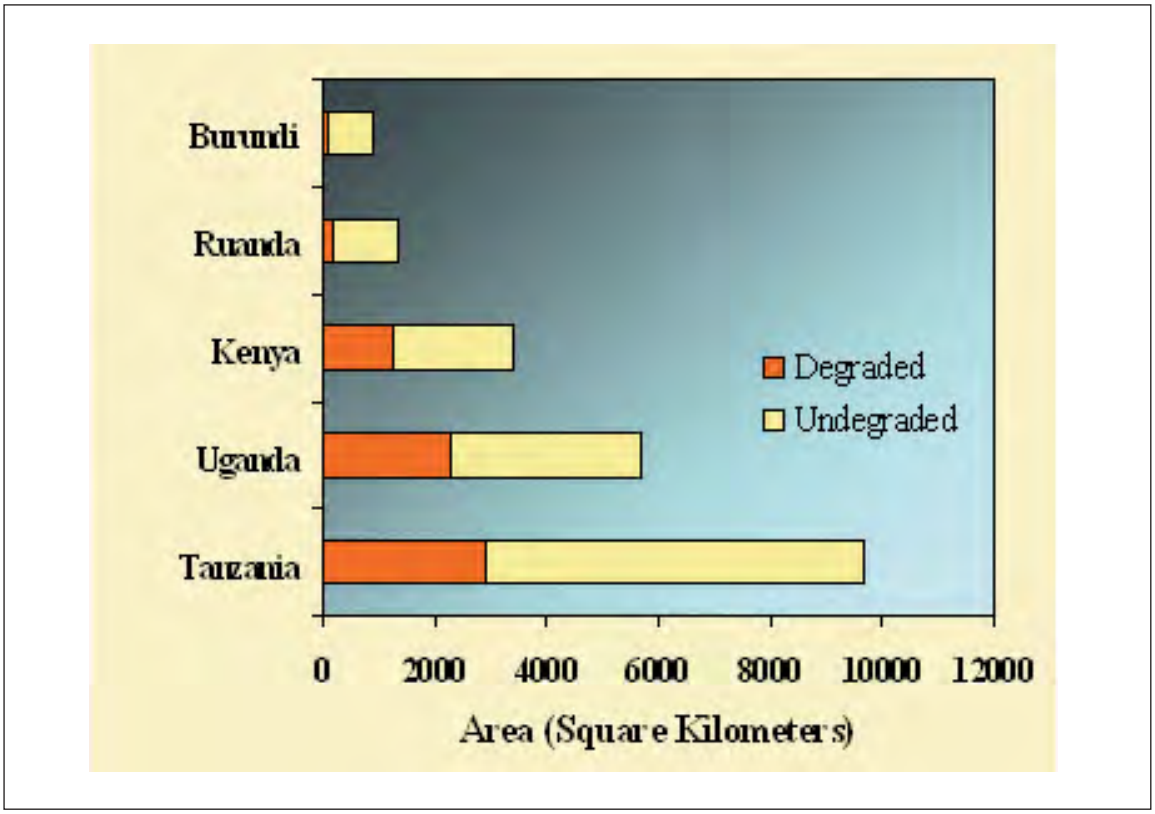

Figure 3: Extent of land degradation in the Lake Victoria basin.

Protecting the land quality for the benefit of people is a major challenge in the basin. Emphasis on agricultural sustainability arises out of increasing awareness about the finite nature of the basin's arable land resources, the widespread problem of land degradation, the rapidly deteriorating quality of the environment and the need to preserve soil and water resources for long-term use rather than for short-term gain. The current population pressure on forests, swamps, rangelands and marginal agricultural lands leads to inappropriate farming practices, forest removal, and overgrazing that, in extreme cases, leaves a barren environment that yields unwanted sediment and damaging stream flow to downstream communities.

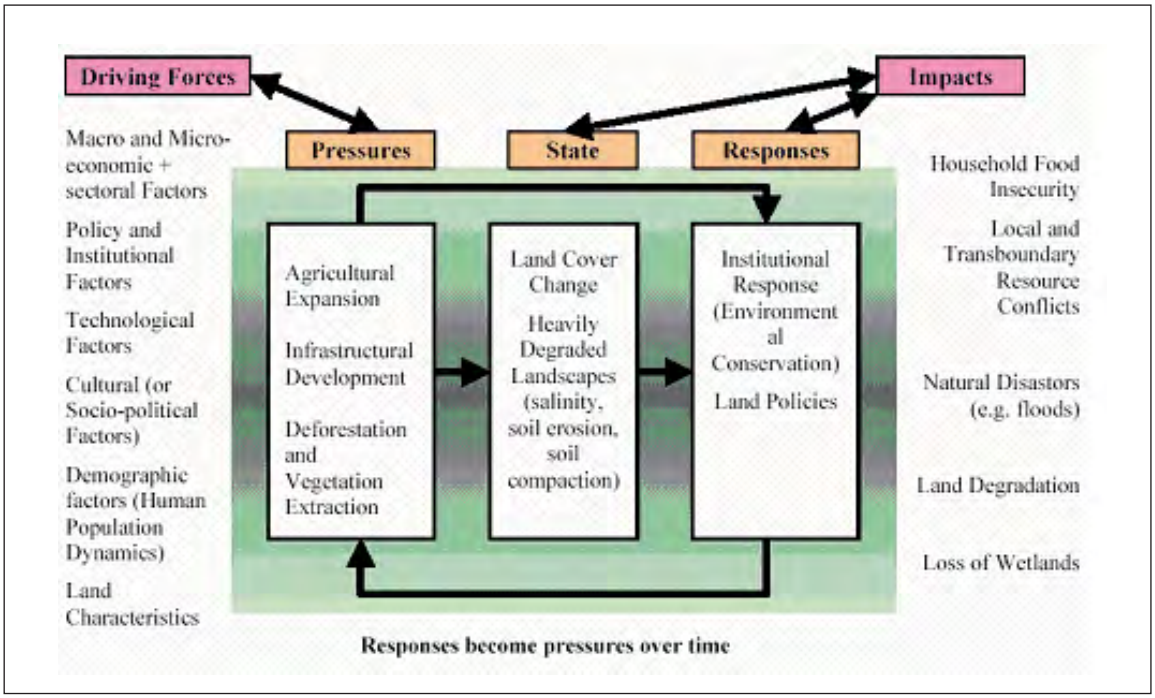

Figure 4: DPSIR framework for assessing land degradation in Lake Victoria basin.

The dilemma in sustainable land management in the basin is that land use changes needed to promote the survival of society over the long-term are at crossroads with what is essential to the survival of the population over the short-term. Presently the ecosystem and the people are vulnerable to the impacts of land degradation. This state is recognizable by several indicators. Severely degraded landscapes dot the basin with infrastructure such as homesteads and roads as well as arable cropland threatened with destruction (Plate 2). The forces of land degradation contribute differently to the problem as shown in Figure 5. Soil erosion (mainly by water) is widespread and lead to a pernicious form of land degradation in many parts of the region.

Soil salinization also poses a major problem in irrigated as well as rain-fed agriculture. Erosion and subsequent sedimentation of rivers and water bodies cause serious pollution concerns for the lake. Sources of pollution are nutrient runoff from agricultural land, urban and industrial waste and biomass burning (ICRAF 2000). From satellite imagery, it can be easily seen that the polluted Nyando river causes a large sediment plume in the lake (Plate 2).

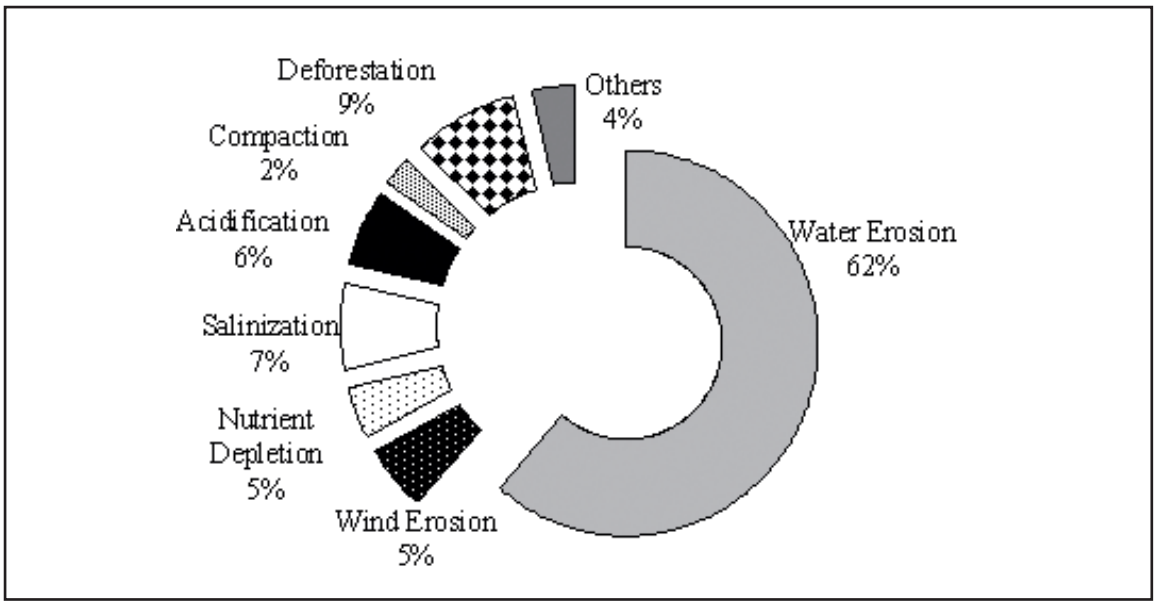

Figure 5: Relative contributions of various degradation factors.

The area around the shores of Winam Gulf is very dry, but it has good potential for irrigated cotton and sugarcane production. The production of rice in the plains at Ahero and West Kano Irrigation Schemes has collapsed owing largely to socio-political conflicts over the land resources and poor maintenance of irrigation infrastructure. Because of land scarcity, some wetlands are cleared for agriculture. During the rainy seasons, however, agriculture is greatly hampered by flooding. The flat terrain has not been effectively protected by dykes erected along the main rivers (Nyando and Awach). The population density is high with about 250 people/km². Marginal grounds and rangelands are therefore used as a result of the high population pressure further worsening the land degradation status as consequence of overgrazing (Plates 3 and 4). The settlements vary from linear trade towns along major roads to scattered homesteads within the flood plain. The settlement patterns of the homesteads and other socio-cultural practices have hampered sustainable management and conservation of the land resources in the area (Ochola and others 2000).

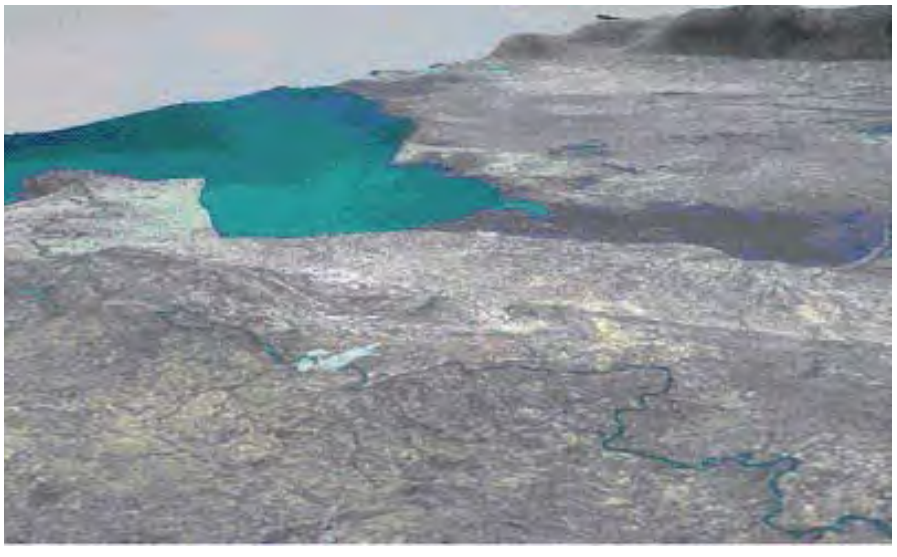

Plate 2: Satellite imagery of sediment plume of River Nyando.

Source: van der Kwast (2002).

Plate 3: Degraded land with receding gullies threatening a homestead.

Source: van der Kwast (2002).

The proportion of the population with access to arable land in the region averaged around 35 per cent over the period 1990-1999 (FAOSTAT 2004) although per capita land holding has been steadily declining in the past thee decades to the current average of about 0.75 ha. There has been progress in land use reforms within the Lake Victoria basin countries, which is expected to create an enabling environment to mitigate against the adverse effects of malign land use practices on land and water resources in the basin. Stakeholder engagement, including community responsiveness to land degradation is being addressed in the new land policies under redrafting in Kenya and other East African countries. Land resource conservation and rehabilitation or reclamation and related technologies should form an integral part of sustainable agricultural development.

Plate 4: Overgrazing in Kano plains.

LAND COVER AND LAND COVER CHANGE (LUCC)

Land cover in the basin area (Figure 6) exhibits both highly spatial and temporal variation. The pattern depends on lithology, geology, topography, the corresponding soil moisture and season of the year as well as human activities.

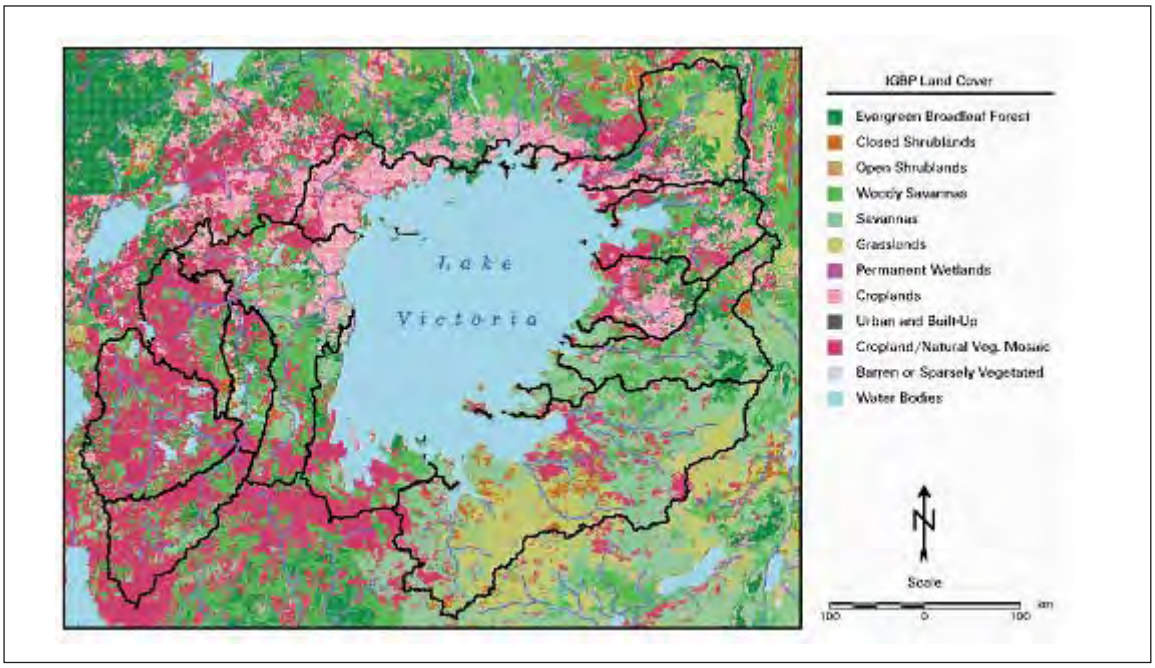

Figure 6: Land cover map of Lake Victoria basin.

In general, uncovering the possible underlying human and biophysical driving forces of land-use/cover change in the region is a formidable task. An analysis of the occurrence of these underlying driving forces and direct causes of LUCC as well as land degradation and their inter-linkages show that identifiable regional and transboundary variations of synergetic cause/driver combinations are significant in the basin. Economic factors, institutions, national policies and remote influences are prominent in the basin. Sub-basin specific patterns of causation can be identified in addition to the more “robust“, proximate and underlying causes. The results have implications for modelling the LUCC process, for policy intervention, and future scenario setting aimed at identifying causality behind land-use and land-cover change in the basin.

Driving forces of land-use change

Undoubtedly, population growth together with the modernization-driven income growth, urbanization, and lifestyle changes will continue to shape the patterns of land use and to drive the changes in land use in the coming two or three decades as they did in the past two decades. Scenarios for each of the major driving forces have been developed and organized to show incremental effects starting from the base year 2004. Poverty, in association with unsustainable livelihoods such as sand harvesting (Plate 5), put undue pressure on natural resources. This accentuates the vicious cycle of high population growth rate, poverty and environmental degradation. The environmental impacts of disasters like flooding in Budalangi Division of Busia and Kano Plains in Nyando District of Kenya are enormous. Transboundary and regional initiatives for the conservation of shared resources straddling international borders need to be pursued.

Plate 5: Sand harvesting along River Awach.

RESPONSES TO AND ALTERNATIVE OPTIONS FOR ACTION ON LAND DEGRADATION

The riparian states have individually enacted environmental laws consisting of legislation, standards, regulation, institutions and administration strategies governing activities on environmental management (LVEMP 2003). The countries are signatories to several multilateral environmental agreements (MEAs) that address several sectors of the environment including land. Some of the MEAs ratified include the Convention on Biodiversity (CBD), UN Convention to Combat Desertification (UNCCD), the UN Framework Convention on Climate Change (UNFCCC), the Montreal Protocol on Substances that Deplete the Ozone Layer, Rotterdam Convention on Prior Informed Consent (PIC), and the Stockholm Convention on Persistent Organic Pollutants (POPS). In order to benefit from the MEAs, the states are also domesticating the New Partnership for African Development (NEPAD) initiative on combating desertification through the respective National Environmental Management Authorities (NEMA).

In addition the following can form useful mitigation options:

- Review of the national and regional agricultural policy in relation, among others, to land tenure systems, sustainable land management and organization for regional economic integration;
- Implementation of policies that influence land tenure and property rights positively with due recognition of the minimum size of land-holding required to maintain production and check further fragmentation;
- Formulation, introduction and monitoring of policies, laws and regulations and incentives leading to sustainable agricultural and rural development and improved food security and to the development and transfer of appropriate farm technologies, including, where appropriate, low-input sustainable agricultural (LISA) systems and environmentally sensitive technologies;
- Development and facilitation of national and regional early warning systems through land degradation and land use change assessment and monitoring;
- Formulation and implementation of integrated agricultural projects that include other natural resource activities such as management of rangelands, forests, and wildlife, as appropriate, and;
- Promote social and economic research and policies that encourage sustainable agriculture development, particularly in fragile ecosystems and wetlands.

SCENARIOS FOR THE FUTURE OF LAKE VICTORIA BASIN LAND RESOURCES

An analysis of future scenarios of the Lake Victoria land resources and land use change is an indispensable element of environmental management that focuses on long-term interactions between economic development and environment. Important factors influencing future land use and land cover may change considerably in the near future. This is particularly true for the environment and natural resources in the countries of the lake basin undergoing social and economic transition. The various scenarios permit the incorporation of several paths of future development in those sectors relevant to land-use change.

The futures featured in the land and land use scenarios are a direct and indirect result of current unsustainable exploitation of the land resources in the basin. The indicators of the various scenarios will be obvious: loss of biodiversity, worsening land cover change, vulnerability to natural disasters such as floods, shortage of arable land, degradation and loss of wetlands. As proxy to these, there will be witnessed poverty and environmental health deterioration. Few studies paint a sustaining future scenario. This would depend on resilient efforts to mainstream public participation in overall integrated land management endeavours and concerted stakeholder outreach focusing on sustainable land management and sustainable agricultural practices. The development of regional and local human development capacity with regard to general education and specifically dealing with environmental conservation may also lead to a realisation of this otherwise unattainable sustainable future. A clear shift towards socio-cultural practices that are in tune with this realisation will obviously be needed coupled with high-level inter-regional co-operation. There is also a need to put more emphasis and confidence on scientific and technological input to meet future land use needs in the region including available arable land.

Land availability in 2025

Land availability forms a binding constraint to land-use requirements in general and for agricultural land uses in particular. Without additional available land, the only choice left for an economy is to increase land use intensity (land productivity) or to increase imports. The foreseen scenarios of land productivity improvement and land availability, demand a clear-cut trade-off between land productivity improvement and net import requirement. This sub-section discusses an estimation of the land availability for the basin in the major land-use sectors for the year 2025 based on current land use patterns.

Productive land is lost not only due to growing land requirements of cities, towns, villages, rural industries, and infrastructure, but also because of degradation caused by natural disasters, water and wind erosion, and other chemical and physical deterioration. To make up for these losses or to even extend the existing land base, farmland reclamation and land reinvigoration is emphasized in the basin's agricultural development. However, conversion of degraded land to productive farmland is very restricted and would require substantive investments. Due to increasing awareness of land scarcity in recent years, it is expected that great efforts will be made to increase land reclamation and to protect agricultural land. Hence, the assumption that degradation-induced total losses of cultivated land, grassland and forestland between 2004 and 2025 could be fully compensated by land reclamation and preservation. This assumption reflects also the policy orientation of the Lake Victoria basin states. Nevertheless, land conversion from agricultural uses to more profitable non-agricultural uses and to settlement and urban uses will certainly continue. The estimates of upper bounds of the land available in 2025 are as presented in Table 1, based on current trajectories of key driving forces like demography, technology, economy and environment.

Table 1: Land Availability (Km²) in 2025[13]

Country	Agricultural Land	Other Crops	Forestland Grassland	Built-up Land	Other
Kenya	316	61	204	255	184
Uganda	527	68	340	425	340
Tanzania	898	203	580	725	493
Rwanda	127	29	82	102	69
Burundi	84	19	54	68	46
Lake Victoria basin	**1953**	**380**	**1260**	**1575**	**1132**

The range of scenarios, which can be developed to quantify how population growth, changes in lifestyles, levels of urbanization and migration, and per capita income growth during the next two decades might affect the demand for different types of land in the region, reflect the effect of future land use change drivers. All the land use types face shortages for the most-aggregate scenarios. If the traditional policy of grain and food self-sufficiency were maintained intact, to keep the farmland requirement feasible, an annual growth rate of land productivity of about 4.5 percent would be required (Swallow and others 2002). It is widely believed that due to prevailing inefficiencies and structural problems, land productivity in the basin's agricultural sector may not have ample room to significantly increase above current levels without having to rely on future technologies. Further productivity growth is also required to compensate for loss and degradation of current cropland. The region requires concepts for infrastructure development that minimize land requirements, especially in the rapidly growing hinterland highlands and urban centres.

There is bound to be witnessed an increasing land stress level that will continue to strain regional food and economic security. If the governments of Kenya, Uganda and Tanzania as well as other Great Lakes states re-orient their land use policies towards efficient use of land and water resources, then food security attainment can be realised by 2025. According to Edwards and others (1996), the key roles that governments play in realising this include:

- Facilitating and institutionalising a policy regime that enhances realisation of full value and benefits of land owner's land use decisions, and;
- Encouraging advances in land use knowledge accumulation and dissemination through research and transfer of land and environmentally sound technology. Such knowledge may include temporal and spatial trends in land quality, agro-ecosystems health as affected by agricultural and other anthropogenic activities.

Other policies must target the eradication of cross-boundary and inter-sectoral land use conflicts. There is need also to couple integrated land and water management with effective population growth strategy and other health and environmental management strategies. Specifically, an integrated land use policy must consider regulated land and water resource exploitation, focused reforms in agricultural incentives and economic diversification away from dominant land-intensive agriculture. These policies would relate to the difficulties of the traditional rain-fed agriculture, uncontrolled urban expansion and the increasing land fragmentation under the existing socio-cultural set-up. Land tenure reforms must enlist the broadest possible participation to be of value to this mitigation process. If not carefully carried out, land tenure reforms may themselves create uncertainty and conflict over land use. The implementation of these rational policies would largely be dependent upon legal, institutional and political will as enabling factors. It is possible to utilise the region's water and land resources on basin and catchment basis rather than on administrative areas. This would demand a review of existing legislation on exploitation of transboundary land and water resources. Economic tools or approaches should be employed in the allocation of land and water resources to competing uses through prudent land use planning.

13 The projections are based on the Stockholm Environment Institute's (SEI) Polestar System with the 2002 baseline data and using "business-as-usual" assumptions.

Strategic implications

In the Lake Victoria basin, there exists a strong link between the environmental and the land use agendas. Indeed, neither the environmental nor the land use pressures in the region can be addressed in mutual isolation. Large numbers of rural people are already changing production techniques away from traditional low-input systems in order to survive. But that change is increasingly taking the undesirable path, away from intergenerational equity. Ample evidence indicates that at present, the path of sustainable land management, that focuses on the reduction of land degradation through strategies for the protection of land quality, including conservation investments and improved environmentally sound land use practices, is largely ignored.

In the region, for the land use agenda to serve its own needs and those of the environment, it must be focused on sustainable intensification in order to close the huge gap between current and potential land productivity. The more fragile land resources in the widespread rangelands that have been rendered unproductive by incremental degradation over the years can be reinvigorated. Although rapid increase in land productivity in these areas is likely to remain difficult, soil conservation, alternative income sources (to reduce stress on land), and modest sustainable increases in productivity based on controlled use of external inputs are key. Sustainable agriculture and rural development policy and programs have an important role to play in helping land users along the path of change that leads to sustainable land management. Box 5 illustrates some approaches to this end. Some of these approaches would include:

- ❑ Promoting sustainable land management as the central theme in land use policies. This should not be done isolation from other sustainable development themes relating to agriculture, trade, investment, research and development, infrastructure and finance. The high economic and social endowment value of land resources and services, and the high costs of unsustainable land use must be emphasized.
- ❑ Encouraging the formulation and implementation of integrated multi-sectoral land use policies at the local, national and sub-regional levels, involving all stakeholders at all stages.
- ❑ Carrying out more intensive research on the socio-economic causes of land degradation and the interactions within and among environmental and sustainability issues in order to define the priority issues and suggest ways of addressing the main driving forces.
- ❑ Improving the coordination between land and environmental audit at all spatial scales for effective sustainability monitoring and evaluation.
- ❑ Assessing the impact of various sustainability pathways.
- ❑ Establishing multi-agency, multi-stakeholder task forces to develop proposals for strengthening regional, local and transboundary coordination and governance structures to protect the land and water resources.

OPPORTUNITIES FOR IMPROVED LAND USE

Integrated water resources management

Any attempts to improve the management of land, wetlands and the inherent water resources in the basin must consider the land-water interactions and the conflicts resulting from decisions made by policy makers, administrators and local land users. There is need to adopt a participatory approach to land and water resources management, thus broadening considerably the scope of the interventions, putting people in the centre of the land management process in order to ensure sustainability. Integrated water resources management (IWRM) regimes for the basin must address the impact of the land conservation practices on the lake and hinterland freshwater resources and reservoirs. There should be local and transboundary water management through low-cost drainage, flood reclamation and water conservation in the basin and its sub-catchments.

Integrated water resources management strategies would open opportunities for addressing primary social and economic courses, including poverty alleviation and a way out of the subsistence farming trap and related environmental degradation in the basin (Odada and others 2004). The water and land

conservation issues are closely related to rural poverty and vulnerability of inhabitants of the basin. Efficient water use and irrigation applied to reclaimed high capability land also would free more water for use in adjacent areas with land but no water. Within the basin, small-scale irrigation based on water harvesting, small reservoirs and shallow groundwater (often highly under-utilized) founded on community work and labour-intensive approaches, has considerable potential.

Management of wetland resources

Wetlands occupy 40.8% of the basin (Gichuki 2003) and belong to the most productive systems in the region and are vital to the local and regional socio-economic development and biodiversity. The success of sustainable management of Lake Victoria basin wetlands must be judged from many different angles, such as stakeholder well-being, government agency satisfaction, and agro-ecosystem integrity. To achieve these outcomes, it will be prudent to refine the key strategies of wise wetland utilization (Gawler 2000). Evidence from the basin indicate that like in other parts of Africa, the sustainable use of wetlands is often endangered when government development and natural resource management policies are insensitive to the wetlands and to the communities who use them (Gichuki 1992; Gichuki 2003). To be appropriate, these policies must address the physical, anthropogenic and ecological threats to wetlands through co-management. There should also be appropriate changes in land tenure, resource access, property rights, and the recognition of co-management regimes in national and local policies, legislation, and development plans and initiatives. Other features of such policies should include:

- Encouraging partnerships between the local people and other stakeholders in participatory monitoring and evaluation of the social, economic, ecological, and biophysical characteristics of the wetlands, and scaling these up towards the community-wide and national land use objectives;
- Ensuring win-win trade-offs and scenarios in which socio-economic development goes hand in hand with wetland resource conservation; and
- Incorporation of indigenous environmental knowledge and technologies in wetlands co-management systems.

The main local level indicators that should be used to measure involvement of indigenous people in the sustainable management of wetlands are highlighted in the Ramsar Convention on Wetlands (1999).

Sustainable agriculture and rural development

Concerted efforts should be made to promote integrated approaches to the planning and management of land resources. This would encompass the development of locally and regionally accepted land quality indicators and appropriate monitoring systems for regular assessment of land conditions, land use and land cover change. Land use monitoring can provide the information required for sound decision-making for the sustainable land management and also to better understand the processes and trends in land degradation, enabling more timely and effective prevention, control and restoration. Land reform must be used as an important tool for poverty alleviation and increasing food security in these areas. The institutionalisation of secure land and water rights will greatly increase the vested interest of smallholders in improving land resources management and investing in land conservation as well as other land improvements.

The application of appropriate technologies to the available land and water can help farmers and policy makers face the myriad significant agro-environmental challenges threatening sustainable agriculture and rural development (SARD) in the basin. Within the overall context of contributing to the achievement of sustainable development in the economies of Lake Victoria basin states, environmentally sustainable systems of agricultural production demand a reduction in environmental damage from farming activities, as well as conserving natural resources, especially land and water, and contributing to the provision of environmental benefits, such as landscapes, bio-diversity, flood control, and land conservation. The demand for sufficient, safe and secure supplies of food and fibre must be met in economically efficient and least environmentally and socio-economically distorting ways by ensuring intergenerational land use equity.

The allocation of land resources to competing land uses must take into account the inherent uncertainties

of the future availability of resources while improving livelihoods of the people in cost-effective ways. This will be achieved through identification of indicators and signals upon which land users, policy makers and other stakeholders can base their decisions. These indicators must relate to 'land resource productivity', 'eco-efficiency', 'green accounting' as well as 'socio-economic parity'. Such indicators may include:

- Adoption of rates of sustainable land management;
- Change in indigenous on- and off-farm biodiversity;
- Change in soil, water and land quality and integrity;
- Local level participation in decision-making, assessment, planning, implementation, and evaluation of integrated and sustainable land management activities;
- Reduced erosion rates and sediment delivery;
- Reduced phosphorous runoff from agricultural land, and;
- Sequestration of above and below ground carbon.

The SARD reforms should target the livestock sector to reduce grazing pressure. Agricultural policy reforms must also contribute to slowing down or halting of the rampant conversion of environmentally fragile rangelands or ecologically valuable land to agricultural or other land uses. They should target significant areas of wetland, forests and natural grassland for preservation through reforms in land user rights. Changes in land use must be encouraged by land use diversion schemes, which provide, over time, incentives to remove the most environmentally sensitive or ecologically valuable land from production to improve land quality through integrated agro-ecosystems management. This must be in the context of appropriate property rights enshrined in the overall land tenure structure.

Sustainable land use technology transfer

The Poverty reduction strategies of the East African states must address land use issues to avoid increasing vulnerability of the population. For instance, Kenya's PRSP Action Plan of September 2002, the current Government's Economic Recovery Plan 2003-2007 and the agricultural revitalization strategy have all identified multi-sectoral approaches to natural resource management as a priority for development. Emphasis has been placed on creating a more demand driven and pluralistic extension system through the implementation of the National Agricultural and Livestock Extension Program (NALEP). The reorientation towards more participatory and demand-driven technology transfer approaches are to be developed and institutionalised through linkages with research bodies like the Kenya Agricultural Research Institute (KARI), Kenya Marine and Fisheries research Institute (KEMFRI) and Kenya Forestry Research Institute (KEFRI) as well as other Non-Governmental Organisations.

The facilitation of research, information, advice, technology transfer and training to farmers should focus on the "public good" aspects of farming practices (ICRAF 2000). Historically, research and development activities have been aimed at developing technologies which, by maximising private profits, have contributed to a large increase in agricultural productivity and output, but which have not always been sustainable. In the past, farmers have often adopted technologies without taking into account the associated environmental costs and benefits. The value of indigenous technical knowledge (ITK) should be considered. The challenge is to identify the best set and combination of scientific and indigenous technologies that work in specific basin circumstances, and define and provide the right incentives and frameworks for their adoption and continued participatory monitoring and evaluation. Rigorous participatory *ex-ante* and *ex-post* assessments and appraisals can help ensure greater follow-through in tracking the adoption of technologies for sustainable farming systems, and in the accountability of research efforts and policies for technology dissemination and adoption.

Early warning and assessment for land degradation and natural disasters

A land degradation early warning system (LDEWS) for Lake Victoria basin would provide data, information, and analyses to decision makers so they can evaluate and anticipate the need for pre-emptive interventions. A major goal of such a system would be to provide timely access to satellite data/ products in order to identify potential or actual problems related to land degradation or natural disasters that may jeopardize the availability or productivity of a given land unit. A programme to create a network of all relevant collaborating early warning partners with improved access to relevant satellite data at key designated periods within the various land use echelons should be institutionalized. Specifically, the programme should (1) provide access to relevant satellite data, (2) collect, archive, manage, and distribute other early warning-related spatial and temporal data, (3) develop web-enabled versions of databases, (4) provide remote sensing and GIS services and analyses, (5) develop and evaluate GIS-environment models for land use/cover change, flood risk monitoring, and land degradation assessment, and, (6) evaluate, recommend and develop new data sources and land quality analysis techniques.

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Lake Victoria: will it support life tomorrow? A case for abatement of pollution and eutrophication of fresh waters

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ABSTRACT

The decline in the quality of water has been associated with human activities in both the catchments and near shore areas. The poor quality of Lake Victoria's water is a result of discharges of untreated sewer and chemical wastes from urban centres as well as microbacterial and nutrient laden runoffs from pastoral agricultural land, shrub-lands, forests and municipal slums. The deterioration of Lake Victoria's ecology is linked to the rapid riparian population growth and consequent livelihood activities associated with farming and urbanization. The review demonstrates that the Lake's water quality has deteriorated to a point that it is no longer able to support aquatic life in the same way it did 40 years ago. The major driving force behind water quality deterioration is population increase. Deforestation, poor agricultural practices, over-stocking and grazing have all contributed to massive soil erosion that continues to convey sediments to the lake. The establishment of institutions that will encourage stakeholder participation in conservation and management of resources at the village, local, national and regional levels is essential for the sustainable utilization of the Lake's resources. The riparian governments need to show both political will and policy direction through establishing policies that engage the public, and enforce existing rules and regulations that will address the water pollution concerns.

Keywords: *Lake Victoria, pollution, eutrophication, sedimentation, phosphorous, Nitrogen, BOD, heavy metals, pesticides*

INTRODUCTION

Lake Victoria has one of the most beautiful and scenic watersheds surrounded by hills on most sides (Figure 1). The lake water is a source of food, energy, drinking and irrigation water, shelter, transport, and serves as a repository for human, agricultural and industrial waste. It has several islands which form the habitats of several bird species, reptiles, other water and land animal species as well as indigenous trees and plant species. The cichlid fish species were estimated to number over 500 in the 1960s, however, recent inventories show these numbers to have appreciably declined (Verschuren and others 2002; Barel and others 1985; Ogutu-Ohwayo 1990; Witte and others 1992).

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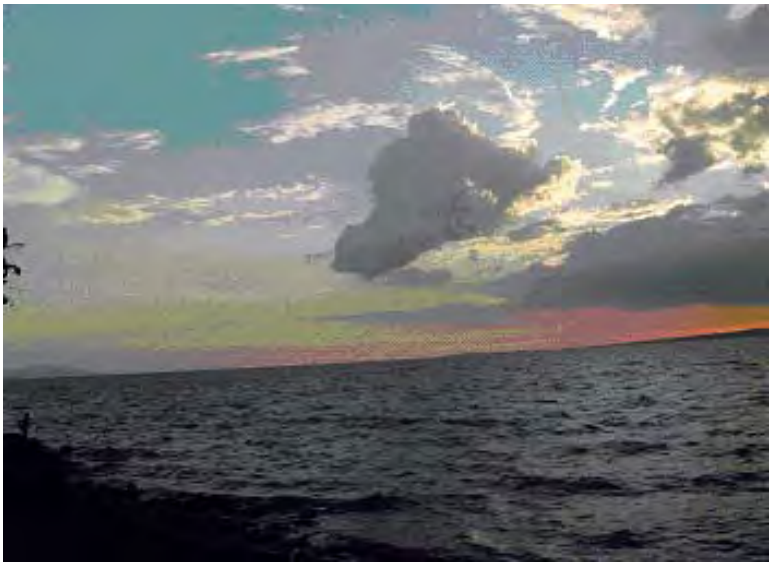

Figure 1: A beautiful sunset over L. Victoria (Photo: S.O. Wandiga).

The decline in the quality of water has been associated with human activities in both the catchments and near shore areas. Historical monitoring data are scarce and hamper apportioning of responsibilities. Furthermore, the dynamic and complex nature of ecosystem changes have not been delineated to allow assessment of the impacts of catchment changes on the lake. What is apparent is that the onset of massive cyanobacteria blooms offshore took place at the same time the indigenous fish stock collapsed. The association of Nile perch (*Lates niloticus* (Centropomidae)) population bloom and decimation of plankton eating haplochromine cichlids (Ochumba and Kibaara 1989; Goldschmidt and others 1993) should be extended to include the cause-effect relationship between the nutrient load pollution of the lake and alien species introduction.

Deforestation coupled with poor agricultural practices have led to an accelerated rate of sedimentation. The high sedimentation rate has been contributed mostly by Kenyan rivers and by Kagera River receiving its waters from Rwanda, Burundi, Democratic Republic of Congo, Uganda and Tanzania. The quality of Lake Victoria's water further suffers a double tragedy by receiving large discharges of untreated sewer and chemical wastes from urban centres as well as microbacterial and nutrient laden runoffs from pastoral agricultural land, shrub-lands, forests and municipal slums. Pesticides have been introduced either directly by fishermen or indirectly through runoff from agricultural areas. Recent evidence indicates that mining activities along the shoreline or upstream may be introducing toxic cyanide and mercury into the lake (Campbell 2000).

The beginning of the slow deterioration of Lake Victoria's ecology is very much linked to the rapid riparian population growth and consequent livelihood activities associated with farming and urbanization. The Lake Victoria Basin (LVB) now supports one of the densest and poorest rural populations in the world (Figure 2). The population has increased from an estimated 3 million in 1890 to 4.6 million in 1932 and stood at 27.7 million by 1995 (United Nations 1995). With the populations of the riparian communities growing at rates that are among the highest in the world (around 3% per year), the multiple activities in the lake basin have increasingly come into conflict with the lakes' ability to cope. Recent population census' show declining growth rates due to the HIV/AIDS pandemic and other diseases. However the rate still remains among the highest in the world (around 2.7% per year) and the populations in the five riparian countries are expected to double again over the next 25-35 years and is estimated to reach 53 million by 2020 (United Nations 1995).

Lake Victoria, directly or indirectly, supports 28 million people who produce an annual gross economic product in the order of US$ 3-4 billion (or 107–143 $US GDP per capita). Over the 1965-95 period the

per capita income levels in Kenya, for example, averaged 2.4% ± 2.6% (95% CI) per annum (World Bank 1998). The Welfare Monitoring Survey implemented in Kenya in 1994 further shows that the incidence of "hard core" poverty was between 40% and 50% in three Lake Basin districts (Bungoma, Busia and Kericho) and between 30% and 40% in four Lake Basin districts (Bomet, Nyamira, Vihiga and Kakamega) (Republic of Kenya 1996; Republic of Kenya 2002a,b). Hard core poverty was defined as total expenditure of less than Ksh 703 per adult equivalent per month, and is thus a much stricter standard than the dollar-a-day rule used by the World Bank. The poverty levels in all the riparian countries are similar to that in Kenya.

EUTROPHICATION AND ITS CAUSES

The quality of the lake water has deteriorated in several respects (Hecky and Bugenyi 1992). The lake depth, bottom oxygen content and transparency (the Secchi index decreased from 5m in 1930 to less than 1m in 1990s) have decreased, while sediment and water phosphorus and nitrogen concentrations have increased (Hecky 1993). Hence the lake bottom is eutrophicated during some seasons of the year. Consequently, strong remediation measures are required to improve municipal sewerage treatment plants, reforest deforested lands, improve agricultural practices and enforce existing laws and regulations at the national and regional levels. There is need to establish new laws, regulations and institutions to manage the lake. Several factors including unchecked soil erosion, municipal and rural wastes as well as residues cause the increase in pollution of the lake from agricultural and other economic activities around the lake.

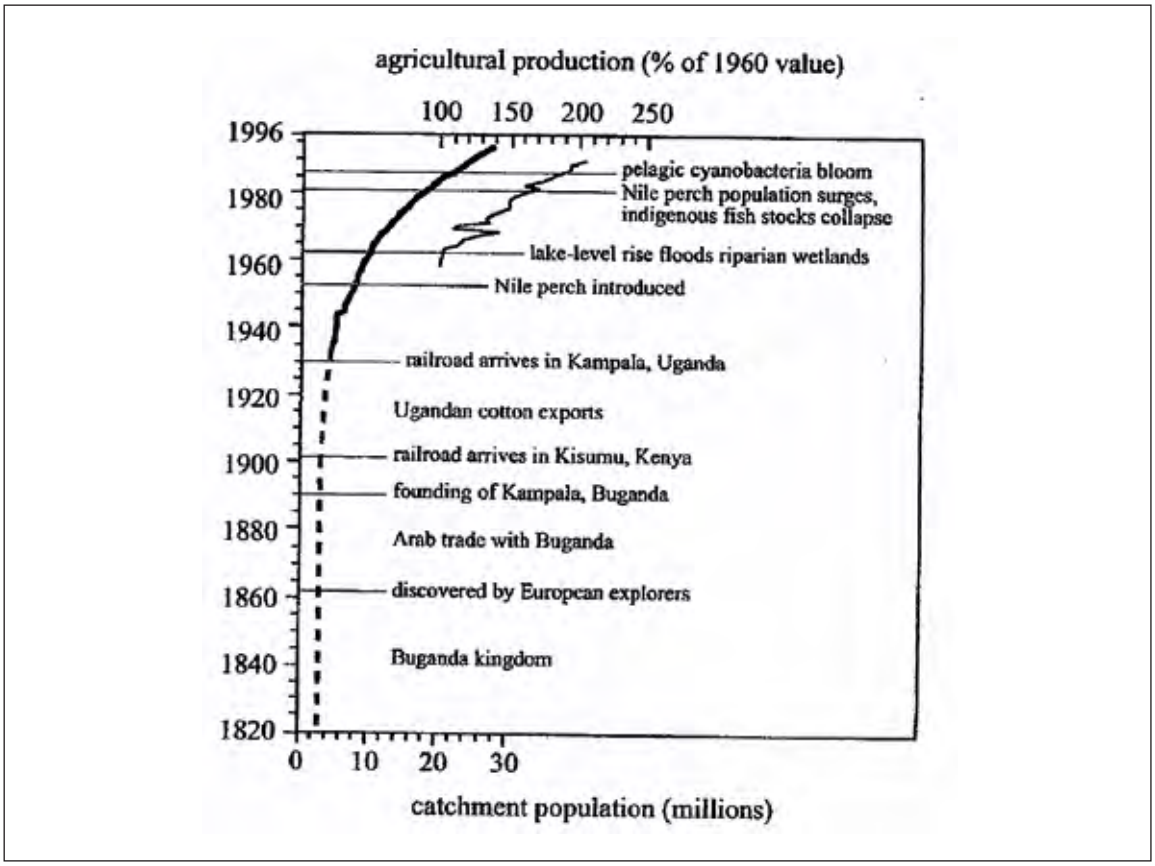

Figure 2: Principal events in the recent environmental history of Lake Victoria, in relation to human-population growth and agricultural production in its drainage basin (Verschuren and others 2002).

Soil erosion, sedimentation and nutrient loading

As the riparian population increased so did the need to grow more food. The expansion of agricultural land necessitated clearing of land and deforestation. Furthermore, bad agricultural practices like cultivating on slopes and river beds have caused massive soil erosion. Increased nutrient flows into the lake coming mostly from agricultural land and forest areas have been estimated to range between 69 x 10^7 kg/yr to 1.98 x 10^{10} kg/yr (Verschuren and others 2002) with resultant plume expansion in the lake (Figures 2, 3). The lake receives 2.3 mm per year of sediment load (silt, P, N and others) (Odada and others 2003; Verschuren and others 2002). Paleolimnological evidence show that most of the land changes and hence sediment deposits occurred after 1940 with the heaviest deposits occurring between 1970 and the early 1980s. The paleolimnological data established a strong chronological link between historical land use and algal production in the lake (Verschuren and others 2002). Therefore, it may be concluded that landscape disturbance rather than food-web alteration or climate change is the dominant cause of the ongoing eutrophication. The high sediment load has brought into the lake high nutrient loads that feeds the water hyacinth (Figure 3).

The rivers in the catchments are the carriers of both sediment and nutrient loads choking the lake. Table 1 gives the rivers and their sediment capacity indices. It is evident that some rivers like Rivers Nyando and Kagera are more prominent in their share of sediment and nutrient deposits. This is because of their percent slope and volume of water carried. The action of Kenya, Rwanda, Burundi and the Democratic of Congo in preventing upstream soil erosion are very critical to the saving of Lake Victoria. This does not exempt Uganda and Tanzania from sharing their responsibility in soil management.

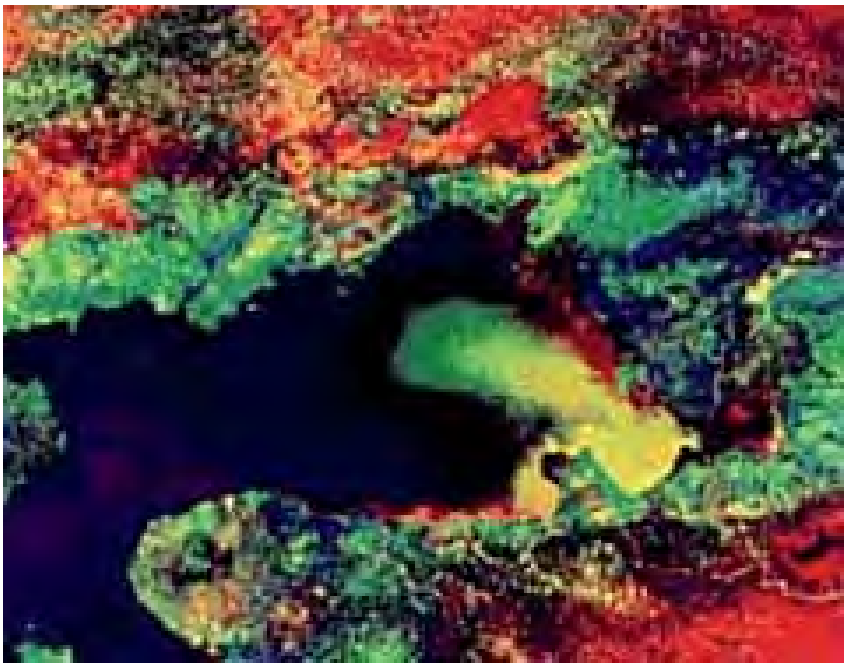

Figure 3: Satellite image depicts a green plume of nutrient rich sediment flowing into Lake Victoria

(Photo Courtesy, ICRAF).

Table 1: Biophysical characteristics of Lake Victoria basin (Shepherd and others 2000).

River basin name	Countries sharing basin	Est. Basin size (km²)	Ave. est. 2000 pop. Density (people/km²)	Est. total pop. in 2000	Ave. annual rainfall (mm)	Ave. sediment transport capacity index*	Ave. % slope
Nzoia/Yala	Kenya	15,143	221(±154)	3,346,000	1,306	0.14	2.3
Nyando	Kenya	3,517	174 (±127)	611,000	1,360	0.30	5.0
Sondu- Miriu	Kenya	3,583	220 (±148)	788,000	1,415	0.14	2.3
Gucha	Kenya	6,612	224(±183)	1,481,000	1,300	0.16	2.0
Mara	Kenya Tanzania	13,915	46(±56)	640,000	1,040	0.15	2.0
Gurumeti	Tanzania	12,290	21(±26)	258,000	879	0.12	1.6
Mbalaget	Tanzania	5,702	37(±22)	211,000	766	0.05	0.6
Duma/Simiyu	Tanzania	9,702	50(±26)	485,000	804	0.06	0.5
Magoga/Muame	Tanzania	5,104	88(±47)	449,000	842	0.05	0.4
Isonga	Tanzania	8,972	48(±22)	430,000	897	0.04	0.3
Kagera	Tanzania/Uganda/ Rwanda/Burundi	59,158	181(±196)	10,711,000	1,051	0.24	3.0
Lake edge	Kenya,Tanzania,Uganda	40,682	133(±175)	5,411,000	1,077	0.21	1.4

Figure 4: Water hyacinth (shown in red) feeds on soil nutrients.

(Courtesy, NASA)

Municipal sewer waste

Prior to the 1960s, Lake Victoria water was clear and filled with life. Today it is murky, smelly and choking with algae. The water quality deterioration has been a result of poor planning, maintenance and inadequate investment in municipal waste-water treatment systems that have contributed to the increased untreated effluent discharge. For example, the Kisumu plant was built to handle 9,000 m³/ day; it discharges 15,000 m³/day of raw sewer into the lake and has been doing so for the past 10

years. An additional 100 tons of human waste is deposited in the lake each day by 120,000 fishermen. Furthermore, runoff from rural and urban areas adds unknown quantities of human and animal waste. Table 2 gives the number of urban centres with sewered and unsewered urban populations in the lake catchments. The combined nutrient load from all sources has contributed to the loss of oxygen and the build up of total phosphorus and nitrogen content in the lake. Lack of oxygen has been measured and appears to vary between shallow waters and deep waters (Hecky and others 1994; Ochumba 1996). In the case of Lake Victoria the concentration of oxygen in the deep ends may be as low as <1 mg O_2/l for up to ten months in a year. Seasonal anoxia is observed in the shallow waters. Other studies have calculated that the year round bottom oxygenation was adequate in the last 140 years before the 1960s. After this the deep-water anoxia started to deteriorate and reached its current spatial extent in the late 1970s (Verschuren and others 2002). Therefore, the loss of oxygen in the lake has been a slow process that took several years to manifest. It has been occurring in the lake for the past 30 years and will take the lake much longer to recover to a life sustaining level if all the nutrient loads were stopped today.

Table 2: Unsewered urban populations in Lake Victoria basin (Scheren and others 2000).

Country	Total population (1000 people)	Sewered Urban population (x1000)	Unsewered Urban population (x1000)	Number of towns
Kenya	10,200	390	630	18
Uganda	5,600	210	870	9
Tanzania	5,200	27	340	4
Rwanda	5,900	-	400	5
Burundi	2,800	-	140	4
Total	**29,700**	**627**	**2,380**	**40**

The extent of eutrophication of a water body is very much dependent on the concentration of phosphorus and nitrogen as these two elements support plant and algal growth (Mugidde 1993). The main source of the two elements is agricultural fertilizer application in the catchments. Figure 5 shows the phosphate load in the catchments (LVEMP 2002). The concentration levels range from 62 to 29,363 t P/yr. Rivers that drain the areas transport the phosphate content to the lake due to high soil erosion in the catchments.

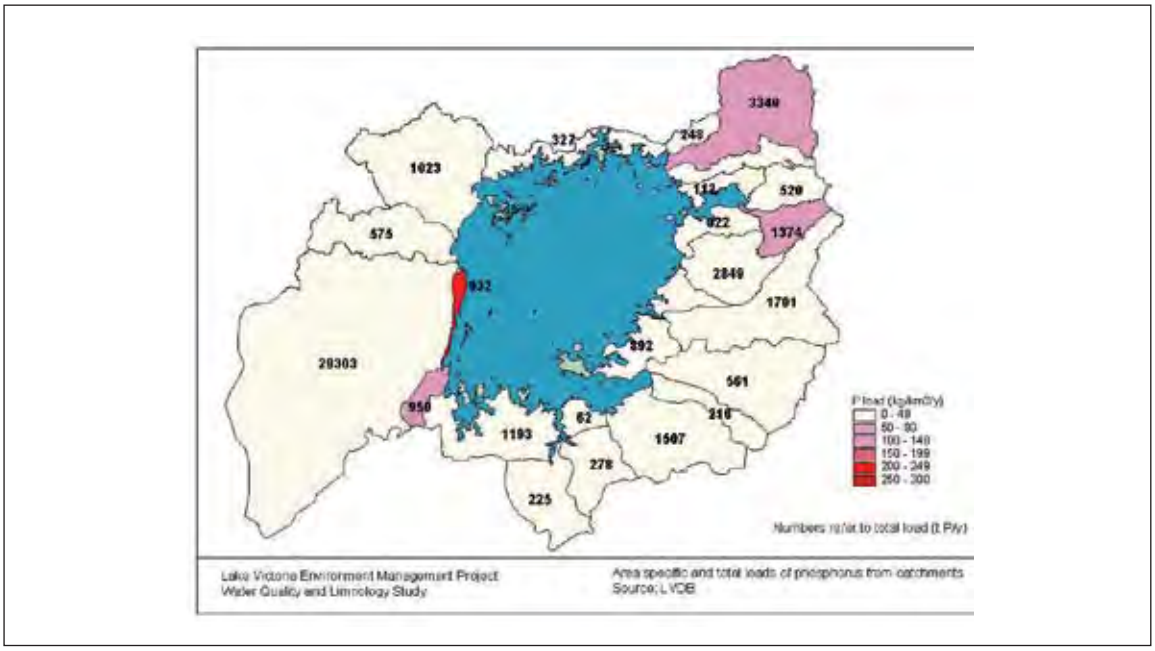

Figure 5: Total Phosphate load from catchments (LVEMP 2002).

Measurements of total phosphorus at point sources in the lake basin show concentrations ranging from 0-730 μg/d (Figure 6, LVEMP 2002). These are high emission rates that have negative effect on the ecology of the lake.

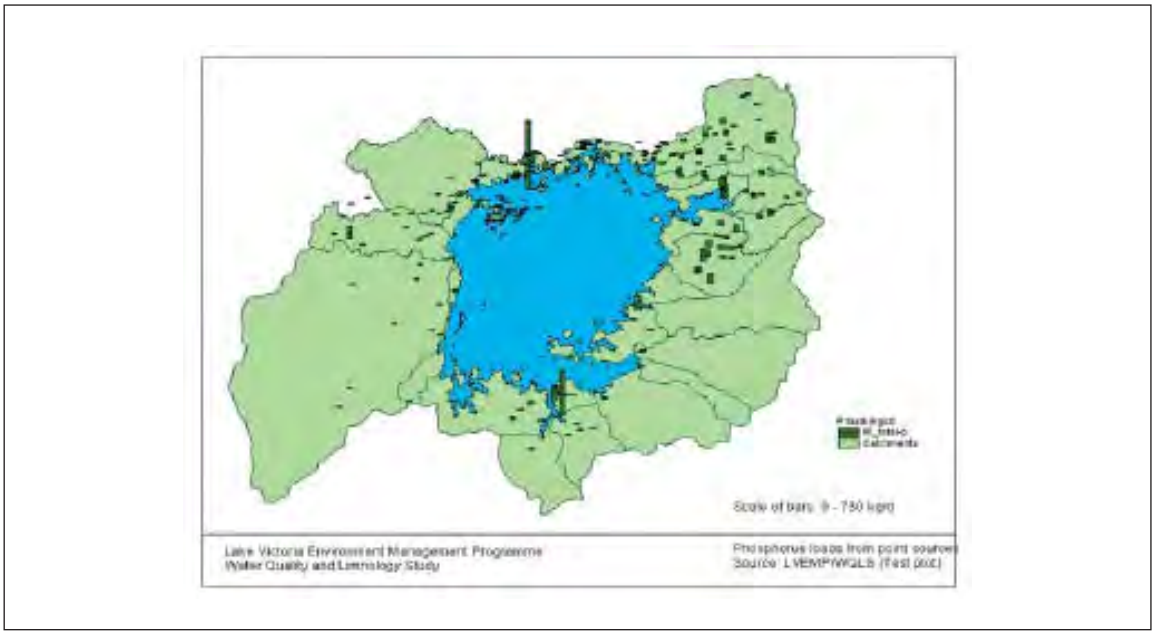

Figure 6: Distribution of point sources of pollution, Total-phosphorus (kg/day) (LVEMP 2002).

There are some few measurements that show surprisingly large amounts of phosphorus coming from the atmosphere. The atmospheric phosphorus originates from biomass burning or transport through global air or regional air circulation. This source is estimated to deposit as much as 15,00-24,400 tP/yr. Figure 7 shows the sources and sinks of phosphorus in the lake. It is important to note from the mass balance that the level of sediment phosphorus is very large and will take, at the present outflow rate, seven decades to reduce to acceptable levels if no further additions are made.

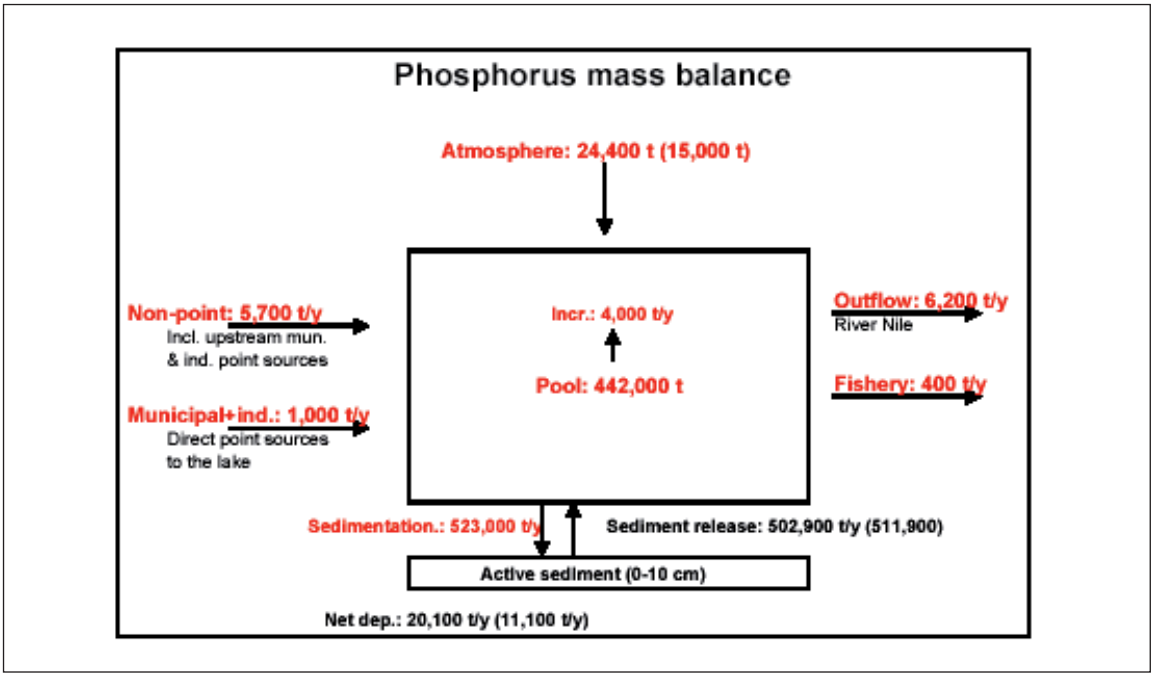

Figure 7: Phosphorus mass balance for Lake Victoria (LVEMP 2002).

The nitrate concentrations in the photic zones have been measured and show high levels. Figure 8 gives some of the measured levels (LVEMP 2002). A summarised mass balance of the nitrates inflow, sinks and outflow through River Nile is given in Figure 9.

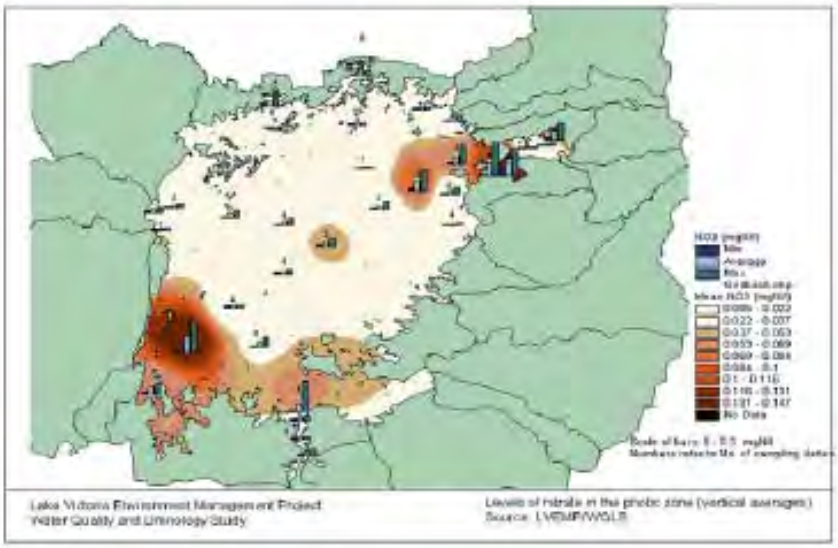

Figure 8: Nitrate concentrations in the photic zone, November 2000 - August 2001.

Source: LVEMP, 2002.

It is again observed that a very large nitrogen inflow is calculated to come from the atmosphere. This is again attributed to either biomass burning or transport from other regions through the global air circulation system. If the rate of sediment deposition is ignored and the possibility of reducing the nitrates levels through outflow in the River Nile alone is considered, then it will take about 85 years to reduce the lake nitrate levels to natural concentration levels. This shows how long and slow a process it is to remediate the lake following pollution. Figures 7 and 9 show the dynamic processes that take place in the lake. Hence the lake rehabilitation process may be accelerated by reducing or eliminating any of the inputs from non-point, municipal or atmospheric sources.

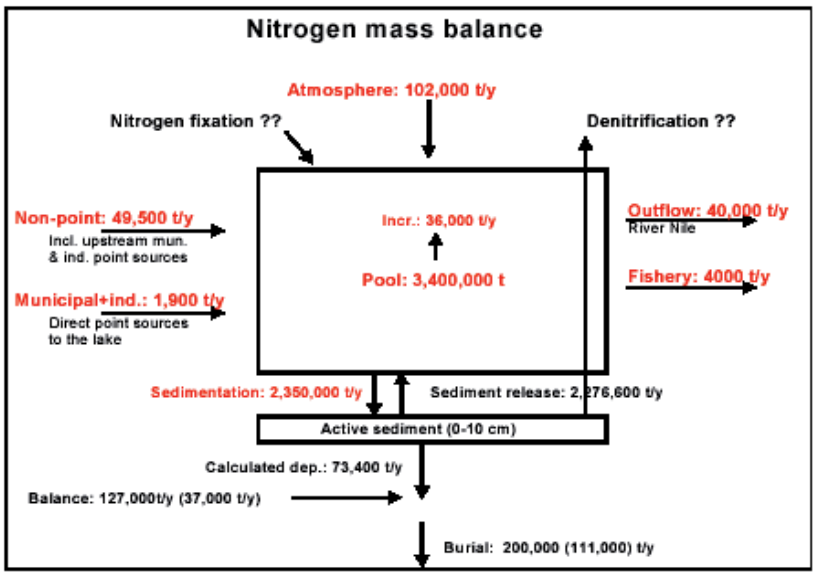

Figure 9: Nitrogen mass balance for Lake Victoria.

Source: LVEMP, 2002.

Threats from chemical pollution need attention

Measurements of heavy metals like copper, zinc, manganese, iron, cadmium, lead and chromium have been carried out in various media of the lake by various researchers (Wandiga and Onyari 1987; Onyari and Wandiga 1989). Tables 3 to 5 give the concentrations of some of these metals in sediments and fish in the Winam Gulf of the lake. Generally, sediments have higher trace metal concentrations than water and other living organisms in the lake. The measured concentrations are within the natural abundance level of non-toxic metals like iron, copper, and manganese. However, the concentration levels in sediments are above those recommended by WHO guidelines for drinking water, 1996/98. The WHO guidelines levels for drinking water require the concentration of the metals to be 0.03 mg/l for cadmium, 0.01mg/l lead, 0.05mg/l chromium, 0.001 mg/l for mercury, 0.5 mg/l for manganese and 2 mg/l for copper.

These levels are rarely exceeded in fish muscles except for lead, which shows concentrations above the WHO (2004) guidelines in most of the sites studied. However, fish scales that are never eaten accumulate high levels of the metals.

Table 3: Comparison of mean content of heavy metals in sediments of Winam Gulf of Lake Victoria (mg/kg dry weight). Mean followed by similar letters are not significantly different at p = 0.05 (Duncan new multiple range test).

Location	Cu	Zn	Cd	Pb	Cr
K.M.F.R.I. Jetty	48.1 b	242 b	1.11 c	92.8 c	37.8 de
Shell Oil Jetty	44.8 bc	268 a	1.36 b	138 a	39.0 de
Esso Oil Jetty	42.0 c	236 b	1.51 a	112 b	41.6 de
Kisumu Port	64.1 a	226 b	1.23 c	110 b	37.1 e
Kisumu Port Jetty	36.1 d	190 c	1.09 c	77.2 d	43.8 d
Mid Bay	25.1 e	133 d	0.82 d	35.5 e	43.5 de
Ndere Islands	26.8 e	127 e	0.61 e	25.8 e	70.8 c
Mbita (West)	7.6 g	17.8 f	0.34 f	2.5 f	82.9 b
Mbita (East)	15.0 f	38.4 f	0.53 e	5.0 f	131 a
SE (Standard Error)	±1.1	±6.3	±0.05	±4.8	±1.9
CV % (Coefficient of Variation)	6.4	7.7	9.4	14.4	6.5

Source: Onyari and Wandiga (1989).

Table 4: Concentration ranges obtained in the muscle and scales of *Oreochromis niloticus* from Winam Gulf of Lake Victoria (*wet weight and +dry weight).

Location	Length class (cm)	Weight class (kg)	Part analysed	Mn (mgkg-1)	Fe (mgkg-1)	Cu (mgkg-1)
Kisumu Town (n=6)	19.00-49.9	0.2-3.0	Muscle*	0.13-0.44	0.73-2.51	0.16-0.26
			Scale	49.95-154	15.35-95.67	1.70-4.52
Kendu Bay (n=9)	50.0	2.5	Muscle*	-	-	-
			Scale	81.97	47.27	2.46
Luanda Bay (n=9)	11.5-53.3	0.525-3.5	Muscle*	0.15-0.69	1.00-3.51	0.22-0.28
			Scale	57.74-131	26.24-157	3.00-5.33
Ndere Isl (n=1)	15.0	-	Muscle*	0.26	3.34	0.26
			Scale	55.57	34.33	3.73
Dunga Beach (n=14)	22.7-37.3	0.3-1.1	Muscle*	-	-	-
			Scale	44.9	35.27-85.52	2.07-5.47
Kisumu Town (n=6)	19.00-49.9	0.2-3.0	Muscle	2^{0}.23-4.35	0.04-0.05	0.41-0.47
			Scale	24.97-107	0.72-1.49	14.11-24.90
Kendu Bay (n=9)	50.0	2.5	Muscle	-	-	-
			Scale	55.02	0.72-	18.49
Luanda Bay (n=9)	11.5-53.3	0.525-3.5	Muscle	2.93-6.25	0.05-0.06	0.49-0.67
			Scale	38.23-183	1.14-2.30	14.99-38.34
Ndere Isl (n=1)	15.0	-	Muscle	5.78	0.04	0.44
			Scale	130	0.97	11.40
Dunga Beach (n=14)	22.7-37.3	0.3-1.1	Muscle	-	-	-
			Scale	49.80-128	0.59-1.86	10.92-19.38

Source: Wandiga and Onyari (1987).

Table 5: Concentration ranges obtained in the muscle and scales of *Lates nilotica* from Winam Gulf of Lake Victoria (*wet weight and +dry weight).

Location	Length class (cm)	Weight class (kg)	Part analysed	Mn (mgkg-1)	Fe (mgkg-1)	Cu (mgkg-1)
Kisumu Town (n=14)	12.5-102	0.125-15	Muscle*	0.13-0.29	0.59-6.40	0.16-0.46
			Scale	2.75-19.30	18.00-126	2.18-4.93
Kendu Bay (n=7)	50.5-64.7	2.5-3.5	Muscle*	-	-	-
			Scale	4.86-12.95	24.77-76.79	3.02-3.39
Homa Bay (n=11)	27.0-115	0.3-24.5	Muscle*	-	-	-
			Scale	3.91-21.79	30.52-131	2.84-4.28
Mbita (n=9)	20.0-76.5	0.125-6.5	Muscle*	-	-	-
			Scale	5.13-15.41	37.05-120	1.99-4.62
Luanda Bay (n=9)	14.5-154	<0.2-0.525	Muscle*	0.15-0.27	1.44-4.04	0.17-0.41
			Scale	4.74-34.77	19.08-105	2.30-6.73
Ndere Isl (n=1)	14.3-31.6	0.2-0.525	Muscle*	0.14-0.35	2.17-3.26	0.18-0.50
			Scale	3.90-9.14	27.14-76.47	2.82-5.18
Dunga Beach (n=14)	25.7-137	<0.2-0.525	Muscle*	-	-	-
			Scale	2.55-26.21	6.59-104	2.54-6.90
Kisumu Town (n=6)	12.5-102	0.125-15	Muscle	2.75-5.22	0.04-0.07	0.39-0.57
			Scale	41.81-213	0.52-1.89	15.46-30.78
Kendu Bay (n=9)	50.5-64.7	2.5-3.5	Muscle	-	-	-
			Scale	42.43-57.22	0.51-1.24	16.63-22.80
Homa Bay (n=11)	27.0-115	0.3-24.5	Muscle*	-	-	-
			Scale	44.13-107	0.94-1.63	17.67-23.18
Mbita (n=9)	20.0-76.5	0.125-6.5	Muscle*	-	-	-
			Scale	67.95-122	1.10-1.69	20.73-27.33
Luanda Bay (n=9)	14.5-154	0.2-55.5	Muscle	3.69-6.10	0.04-0.08	0.42-0.74
			Scale	41.34-224	1.24-3.08	16.50-33.65
Ndere Isl (n=1)	14.3-31.6	0.2-0.525	Muscle	3.45-4.42	0.05-0.09	0.45-0.91
			Scale	41.28-123	1.00-1.70	16.83-33.45
Dunga Beach (n=8)	25.7-137	0.170-35	Muscle	-	-	-
			Scale	40.29-161	0.45-1.46	11.28-28.63

Source: Wandiga and Onyari (1987).

It is important to note that there is a dynamic equilibrium between sediment concentration and other media concentrations. Sediment serves as a replenishment source for the other media. Despite the relatively low concentrations of the trace metals, their ability to bio-accumulate through the food chain is emphasized. It is for this reason that the levels of lead found in fish and which most likely came from leaded gasoline used by boats, is of critical concern. Similar concern holds for mercury which is used in gold extraction and whose level has been detected in 5-10 kg Nile perch fish muscle at a concentration of 200 ng/g (Campbell 2000).

Pesticides residues

Various pesticides used mainly in agriculture have been detected in soil, water, fish and weeds in the lake (Table 6). In general, very limited work on determination of persistent organic pollutants residues in the Ugandan environment exists. Of particular concern have been organochlorine pesticides. In previous studies dieldrin was detected in milk from cows (Kiremire 1997) and both dieldrin and lindane were detected in milk from cows (Ejobi and others 1994). In a more recent study of levels of organochlorine pesticides in the aquatic lake system, it was concluded that the ratios of DDT to DDE from the samples analysed suggests previous use of the pesticide DDT (Kasozi 2001). The study further suggests a

significant use of lindane and endosulfan within the lake region (Waswa 1997; Ejobi and others 1994; Mbabazi 1998). Pollution of the Lake's waters by pesticides has also been reported in the Tanzania parts of the lake in various studies (Aryamanya-Mugisha 1993; IUCN 1992; Henry and Kishimba 2000).

Table 6: Comparison of pesticide residues in water from Rivers Sio, Nzoia and Lake Victoria (µg/l).

Pesticide	R. Sio (n=9)	R. Nzoia (n=9)	Sio Port Beach (n=9)	Marenga Beach (n=9)
α-HCH	0.02-0.03	0.01-0.04	0.01-0.05	0.01-0.3
α-HCH	0.01-0.05	0.01-0.06	0.01-0.05	0-0.10
α-HCH	0.04-0.11	0.04-0.06	0.05-0.09	0.03-0.07
p,p'-DDT	0.02-0.13	0.07-0.09	0.07-0.09	0.01-0.09
o,p'-DDE	0.08-0.16	0.02-0.15	0.02-0.09	0-0.09
p,p'-DDD	0.02-0.10	0.08-0.18	0.07-0.14	0.04-0.18
α-Endosulfan	0.12-0.23	0.05-0.11	0.02-0.15	0.06-0.13
Endosulfan sulphate	0-0.19	0.07-0.10	0.01-0.15	0.07-0.14
α-Endosulfan	0.09-0.18	0-0.14	0.03-0.09	0-0.09
Aldrin	0.17-0.34	0.03-0.20	0.07-0.14	0.05-0.10
Dieldrin	0.07-0.10	0.18-0.36	0.09-0.18	0.12-0.31
Endrin	0.03-0.17	0.05-0.22	0.08-0.11	0.04-0.09
Heptachlor	0.03-0.17	0.10-0.15	0.08-0.15	0.05-0.10
Heptachlor e	0.03-0.15	0.06-0.12	0.08-0.15	0.05-0.11
Methoxychlor	0.02-0.86	0.02-0.08	0.04-0.07	0.02-0.14

Source: (Madadi 2004).

Table 6 shows the widespread presence of most organochlorine pesticides that are still used in the Kenyan catchments. The levels detected are much lower than the WHO guidelines for daily intake of drinking water. However they become significant considering magnification through the food chain. The detected levels in sediment (Table 7) are considerably higher than those found in water. Sediments are reservoirs of pollutants and do release back to the water the same pesticides in order to keep the equilibrium balance. Bottom feeder fish ingest soil and thus expectedly have higher concentration of pesticides in their body. Identical pesticides have also been detected in weeds (Table 8) collected from the same sites as other samples in the rivers and the lake. The weeds exhibit higher concentration of pesticides than that found in the water but lower than that in the sediments. The pesticides residues in the muscle of *Tilapia zilli* (Table 9) showed a wide variation with a mean much higher than in water and weeds but lower than in sediments. The high concentration of total DDT is significant given the reported banning of it.

Pesticides have also been reportedly used for killing bird pests (Sentongo 1998) and in illegal fishing (IUCN 1992). Indeed, the banning of fish exports from Lake Victoria to the European Union in 1998 followed the misuse of the pesticide to kill fish for sale by unscrupulous fishermen (European Commission 1999). During that year alone, more than six cases of fishing with endosulfan were reported leading to drastically reduced sales in both local and international markets (Lugudo, Government Chemist, Uganda 1998). This resulted in the imposition of a fish import ban by the European Union on all fish from Lake Victoria. Commercial fishing around the lake and subsequently the economies of the three riparian countries were greatly affected as a result. Total loss of income due to the ban was estimated to be more than US$ 300 million (European Commission 1999).

Table 7: Comparison of pesticide residues levels in sediments from Rivers Sio, Nzoia and Lake Victoria (µg/kg).

Pesticide	R. Sio (n=9)	R. Nzoia (n=9)	Sio Port Beach (n=9)	Marenga Beach (n=9)
α-HCH	3.55-5.16	3.87-6.94	1.81-6.06	0.91-7.78
α-HCH	2.7-4.00	1.34-4.19	0.92-3.59	0.52-2.33
α-HCH	2.07-18.25	5.56-27.09	6.23-24.54	3.37-23.12
p,p'-DDT	2.56-19.39	14.73-20.42	7.16-12.57	1.62-12.32
o,p'-DDE	3.97-13.87	9.63-10.62	0-6.21	5.15-10.53
p,p'-DDD	9.11-39.54	21.56-24.20	13.16-19.49	10.72-18.91
α-Endosulfan	16.50-25.50	11.04-49.11	5.96-22.47	0.12-13.45
Endosulfan sulphate	11.26-15.56	10.32-25.97	2.88-13.17	6.72-13.06
α-Endosulfan	0.01-0.32	0.02-0.12	0-0.05	0-0.03
Aldrin	6.15-57.32	9.41—27.76	11.71-12.71	11.44-20.78
Dieldrin	22.07-65.48	30.65-51.92	16.03-57.01	11.94-69.55
Endrin	7.07-12.76	14.07-26.86	8.64-18.13	8.00-10.99
Heptachlor	8.25-16.59	17.24-27.99	2.49-10.00	13.76-30.83
Heptachlor e	3.40-40.00	4.06-21.70	3.20-8.76	3.24-6.31
Methoxychlor	2.61-8.13	7.82-37.47	2.52-14.78	3.45-4.41

Source: Madadi (2004).

Table 8: Comparison of pesticide residues levels in weeds from Rivers Sio, Nzoia and Lake Victoria (µg/kg).

Pesticide	R. Sio (n=9)	R. Nzoia (n=9)	Sio Port Beach (n=9)	Marenga Beach (n=9)
α-HCH	0.55-1.46	0.36-1.92	0.68-1.04	0.45-1.90
α-HCH	0.21-1.99	0.26-1.30	0.21-0.83	0.46-0.83
α-HCH	0.72-5.23	0.87-6.45	1.04-1.90	1.43-2.87
p,p'-DDT	0.64-6.23	1.50-4.98	1.24-3.08	1.82-4.54
o,p'-DDE	0.89-3.41	0-7.84	1.01-2.66	0.86-4.82
p,p'-DDD	3.78-8.75	4.04-8.89	2.14-3.81	2.19-8.22
α-Endosulfan	1.47-3.08	1.27-3.82	1.14-1.70	0-2.68
Endosulfan sulphate	0.47-2.90	1.26-4.20	1.06-3.20	1.29-4.15
α-Endosulfan	0.05-0.73	0-0.17	0-0.67	0.02-0.18
Aldrin	2.40-7.20	2.46-7.55	2.21-3.55	2.51-5.52
Dieldrin	4.52-10.07	3.56-8.59	3.15-6.73	3.59-7.51
Endrin	1.64-2.85	2.21-4.52	1.16-3.13	0-3.85
Heptachlor	1.22-2.86	1.06-2.51	0.93-2.32	0.50-3.15
Heptachlor e	0.90-2.85	0.62-4.20	0.42-0.84	0-2.65
Methoxychlor	1.13-1.81	1.56-3.09	0.12-3.09	1.21-2.40

Source: (Madadi 2004).

Table 9. Comparison of pesticide residues in muscles of *Tilapia zilli* from River Sio and Lake Victoria (µg/kg) (Madadi, 2004)

Pesticide	River Sio (n=9)	Sio Port Beach (n=9)	Marenga Beach (n=9)
α-HCH	0.70-3.26	0-1.58	0.11-4.11
α-HCH	0.10-2.87	0-3.57	0.06-2.45
α-HCH	2.01-18.99	0.59-25.05	1.05-14.98
p,p'-DDT	21.30-99.19	4.63-85.35	6.63-104.89
o,p'-DDE	5.17-26.68	3.80-15.61	9.99-18.95
p,p'-DDD	150.85-481.18	8.28-176.87	10.81-415.96
α-Endosulfan	0-23.26	0-218.08	0-80.59
Endosulfan sulphate	0-37.38	9.86-25.76	8.36-134.75
α-Endosulfan	0-0.72	0-0.09	0-0.07
Aldrin	14.26-52.19	0.29-40.61	0.27-30.01
Dieldrin	199.28-213.43	87.55-255.45	7.88-128.98
Endrin	0-54.38	0-19.87	0-18.94
Heptachlor	4.17-29.38	0-44.63	0-14.84
Heptachlor e	0-42.11	7.01-14.75	0-14.06
Methoxychlor	0-9.01	0-3.51	0-3.51

Source: (Madadi 2004).

Gold mining: A new problem to Lake Victoria

Large deposits of gold have been discovered in the Mwanza region of Tanzania. Table 10 gives the known deposits in the region with companies licensed to mine them. Existence of gold is not restricted to the Tanzanian side of the lake but artisans in Kenyan and Ugandan sides of the lake have exploited veins of gold. Gold ores are commonly associated with quartz and pyrites with lesser amounts of chalcopyrite, arsenopyrite and galena. The element mercury and compounds of cyanide, especially hydrocyanide, are often used in the extraction and panning of gold. A recent study of fish has shown mercury presence in large Nile perch, weighing more than 5-10 kilograms (kg) with concentrations usually exceeding 200 ng/g in fish tissue (Campbell 2000).

Machiwa (2003) studied mercury concentration in lake water and found it to be generally below 1 ppb. The highest methyl mercury that was recorded in Mwanza and Mara regions was at Ikungu (5.05 ppb). Other water samples collected at more than 10m from the shoreline had methyl mercury content less than 0.01 ppb, suggesting slow mixing of waters or rapid uptake by sediments of Ikungu area. There is a likelihood of exposure to high Hg intake by using lake water at Ikungu site for household chores especially soon after gold ore washing activities. Secondly, bacterial fixation of methyl to mercury would increase the level with time. Other areas that had methyl mercury concentration in lake water close to 1 ppb were Lukumbo (1.02 ppb), Simiyu river mouth (0.9 ppb), Mirongo river mouth (1.46 ppb), Suguti (1.10 ppb) and Shirati Bay (0.82 ppb). Occurrence of Hg in offshore water samples is suggestive of other means of transport rather than surface runoff.

Mercury concentration in lake sediments was generally less than 0.01 ppm except at a few locations (Ikungu, Magu Bay and Mori Bay) where the concentration was approximately 1 ppm. Mercury concentration in the sediment was not related to organic matter content. Environmentalists from Tanzania and Uganda have clearly expressed their opposition to gold mining, and warned that there is a high risk that sodium cyanide, a strong poison used to extract gold from ore, might leak into the lake through the rivers (Campbell 2000).

Table 10: Gold Deposits of Lake Victoria Area.

Geita	6.4M oz Au	4.05 g/T Ashanti-Anglogold
Golden Pride	2.7M oz Au	2.6 g/T Resolute Mining
Bulyanhulu	10M oz Au	14.0 g/T Barrick
Kahama Project	26M tons	2.3 g/T Pagaea-Anglogold
Tulawaka	1.7M tons	19 g/T Pagaea
Buckreef-Rwamagaza	0.36M oz Au	3.1 g/T Spinifex
Nyakafuru	0.14M oz Au	5.7 g/T Spinifex
Chocolate Reef	1.9M oz Au	2.3 g/T Angola-Pagaea
Golden Ridge	1.6M oz Au	1.4 g/T Barrick-Pangaea
Kitongo	0.33M oz Au	1.34 g/T Ashanti-Spinifex
Kukuluma-Matandani	1.96M oz Au	2.87 g/T Ashanti
North Mara	2.06 oz Au	3.17 g/T Africa Mashariki

CONCLUSION

The review has clearly demonstrated that the Lake Victoria water quality has deteriorated to a point that it is no longer able to support aquatic life in the same quantity and quality of the past 40 years. The major driving force behind water quality deterioration is population increase. Reorganization of the rural villages into self-supporting, well-serviced utilities urban centres will free land for cultivation that can be properly planned and managed. Review of the land tenure system in the catchments is an essential first step to the restoration activities of the lake. Deforestation, poor agricultural practices, over-stocking and grazing have all contributed to massive soil erosion. Enforcement of laws governing agriculture, forest, land and water conservation will lead to sediment and nutrient load reduction. There is a need to apply a mixture of command and control laws and regulations as well as market forces to effect change. Some market price adjustment for fertilizers and pesticides will introduce their conservative use.

The planning of urban and rural centres will lead to the provision of waste treatment plants, potable water, electricity, roads and other utilities. Once utilities are provided there should be sufficient financial resources to ensure that systems of installed infrastructures are maintained and operational at all times. Most sub-Saharan African countries have very weak systems for operation and maintenance. The quality of our environment cannot be maintained if utilities are non-functioning. Hence sufficient resources need to be budgeted for each year for operations and maintenance. It is similarly critical that all municipal waste treatment plants that are in disrepair are brought to function as soon as possible. Trained staff should be engaged to ensure their continued service. Market forces should be put in place to reward or penalize the offenders. Enforcement of the polluter pays principle is an incentive to ensure that profits are not wasted in paying taxes and fines.

Establishment of institutions that will encourage stakeholder participation in conservation and management of resources at the village, local, national and regional levels is essential for the Lake Victoria resources utilization. Some of these institutions already exist. One such institution is the Lake Victoria Fisheries Organization (LVFO). This institution with its similar sister fisheries research institutes should be strengthened to enable them mobilize communities and resources for the management of the lake and not only its fisheries resources. Similarly, the East African Community could play a stronger role in regional policy coordination. At the national levels, the respective riparian government should show both political will and policy direction in establishing policies that engage the public (public awareness, voluntary groups, the mass media, others), enforcing existing rules and regulations and where deficient making new ones, and establishing policies that use existing markets (often use price signals) and create markets (often create price signals).

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Aquatic biodiversity of Lake Victoria basin

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ABSTRACT

Lake Victoria is the largest lake in Africa, with the largest freshwater fishery in the world. There are nine main affluent river basins (Sio, Nzoia, Yala, Nyando, Sondu-Miriu, Awach, Kuja, Mara, and Kagera), and one surface outlet, the River Nile. The basin has extensive wetlands and small water bodies, which have (or had) a hydrological connection with Lake Victoria and therefore constitute potential "refugia" for biotic and genetic diversity from the main lake. The biological diversity in these waters is known to be exceptional both in number of species and in their endemism. While the ecosystem changes have been documented, causes of these changes remain uncertain due to lack of basic data on the abundance and diversity of the biota. Through the Lake Victoria Environmental Management Project (LVEMP), the three riparian states of Kenya, Uganda and Tanzania, with assistance from the Global Environmental Facility (GEF) and the International Development Agency (IDA) have collectively responded to the issues of ecosystem and resources degradation in the lake basin. Areas of concern which constituted specific components of the project were declining fisheries, proliferation of the water hyacinth, extreme sediment and pollution loads in the river and lake waters, reduced vegetation and forest cover in the catchment, wanton clearance and draining of wetlands and poor land use practices in and around the basin. One of the critical components of LVEMP therefore concerned Fish Biology and the Conservation of Aquatic Biodiversity. This document provides information on the pertaining situation of the basic biodiversity in the Lake Victoria basin. The composition, diversity, distribution as well as the ecological and socio-economic importance of the various species have been presented. The communities discussed include macroinverterbrates, phytoplankton, macrophytes, invertebrates, and vertebrate. The need for more studies to ensure sustainability as a result of the ongoing exploitation is emphasised.

Key words: *Lake Victoria basin, Biodiversity, Macroinverterbrates, Aquatic ecosystems, satellite water bodies, Algal Communities, Phytoplankton, Macrophytes, Invertebrates, Vertebrates*

INTRODUCTION

Lake Victoria experienced dramatic changes in the past century. These changes occurred in the drainage basin involving the vegetation, industrialization, agricultural developments, introduction and invasion of alien species and intensive non-selective fishing. These, among other factors, have led to destruction of native and endemic components of the Lake Victoria basin. Lake Victoria lost about 60% of its cichlid taxa in the last decade and faced deterioration in water quality from over exploitation of the fishes and human impacts on the ecosystem (Witte and others 1992a,b; Kudhongania & Chitamwebwa 1995; Gophen and others 1995; Ogutu-Ohwayo and others 1997). Other components of the aquatic system that changed included algae, macrophytes, invertebrates, birds, amphibians and reptiles that are important parts of the ecosystem. There has been progressive build-up of physical and chemical changes in Lake Victoria. Increased chlorophyll "a" concentration and primary production, a decrease in silica and sulphur concentrations compared to values measured 30 years ago was noted (Hecky 1993). Other ecological shifts include the dominance of blue-green algae and leading to increased algal blooms.

A number of endemic species of fish and birds in Lake Victoria basin face various threats from a variety of human activities. In 1988, about one hundred native fish species endemic to Lake Victoria were entered in the World Conservation Union's Red Book of endangered species. A number of studies report remarkable post perch structural changes directly impacting on the niche composition at all levels of biodiversity (Mbahinzireki 1994; Mugidde 1992; Gichuki & Odhiambo 1994; Seehausen & Witte 1995; Seehausen 1995; Chapman and others 1995). The wetland ecosystems in Lake Victoria basin are rich with vertebrates. Other than fish most of these are not well studied. It is reported that Kingfisher (*Ceryle rudis*) diet changed from haplochromines to dagaa (Omena) following the explosion in Nile perch population (Goudswaard & Wanink 1994). The ecosystems are quite diverse and provide different ecological niches or habitats for different species. The rivers and their associated wetlands provide *refugia* for fish species endangered from Nile perch and other predators (Chapman and others 1996). Some species, thought to have disappeared following the perch introduction in the lake, have been found in satellite lakes and other *refugia*. Some of these species or populations could recover under effective ecosystem management.

The lake basin is estimated to have a population of 30 million people which is growing at > 3% per annum. The lake supports one of the most productive freshwater fisheries in the world with annual fish yields in excess of 500,000 tonnes annually. Other economic activities in the lake basin include agriculture, mining, hydropower generation and transport. Three major cities (Kampala, Kisumu and Mwanza) with a combined population of at least six million people depend on the lake for domestic and municipal water supply and waste disposal. The challenge on Lake Victoria is to sustain the lucrative fishery that emerged out of the Nile perch introductions, and at the same time restore and conserve the lost fish diversity.

Diversity of Aquatic ecosystems in the Lake Victoria basin

Lake Victoria, the largest tropical lake in the world, is shared by the three East African states: Kenya, Tanzania, and Uganda. Lying at an altitude of 1134 m above sea level with a surface area of 68,800 km^2 and a shallow depth (92m max. depth), the lake is almost a square saucer (with max. length and width of about 400 km and 320 km respectively) dipping out into the White Nile. Much of the lake is shallow (≤ 40 m). The catchment area is about 194,200 km^2. Located between latitudes 0° 20' N, 3° 0' S and longitudes 31° 39' E, 34° 53' E, the lake is truly equatorial. The bottom has a thick carpet of soft organic mud, broken only in isolated patches of hard substrate, sand or rock. It has a highly indented coastline with many bays and gulfs. The Kagera and Nzoia Rivers are the major inflows while the major out flow is via River Nile.

Lake Victoria and its small satellite water bodies (SWB) in Kenya

About 6% of the total lake area lies in Kenya, most of this being the Nyanza (Kavirondo or Winam) Gulf (Figure 1). The Gulf joins the main lake through the Rusinga channel. The causeway that links Rusinga Island to the mainland blocked Mbita Channel, severing the only other connection with the main lake. The blocked current flow and exchange of water between the gulf and the open lake severely affect the water quality in the gulf. The catchment of the Kenya portion of Lake Victoria covers approximately 47,709 km^2 and has numerous rivers, small lakes, dams and streams (Figure 1) collectively referred to as Satellite Water Bodies (SWBs). Notable among the SWBs are lakes Kanyaboli, Sare, Simbi and Namboyo; and rivers Sio, Kibos, Nzoia, Yala, Nyando, Sondu-Miriu, Awach, and Kuja. Other smaller lakes are Tinga Migowa (34°46'S, 34° 32' 03 E), Achoro (0° 30' 48 S, 34° 32'00 E), Aimo (0° 32' 23 S, 34° 36'56 E), Uranga (0° 05' 32.4 N, 34° 16' 33.2 E), Mauna (0° 12' 31 6 N, 34° 09' 26,3 E), Ulanda (0° 05' 57 N, 34° 09' 53 E), Mwer (0° 07 12' N, 34° 10' 19.8 E), Ugege (0° 13' 3.2 N, 34° 12' 34.6 E) and Ufinya.

Most of these SWBs are surrounded by extensive papyrus swamps save for the steep sided Lake Simbi, which lies in a crater with hot springs that do not support papyrus growth. Lake Kanyaboli with a surface area of about 10.5 km^2 is located at 0°05' 32.3 N, 34° 16' 33 2 E. It receives its waters from River Yala. The lake has no direct outlet but discharges its water to Lake Victoria through underground seepage. Most of the dams were sunk in the 1940s and 1950s to provide water for domestic and livestock uses. Fish endemic to Lake Victoria were introduced into some of these dams and lakes to supplement fish

yields and resource value. The SWBs are the remaining refuge to those endemic species, now feared to have disappeared from the main Lake. The stocks in these SWBs are well established and contribute immensely to the biological diversity.

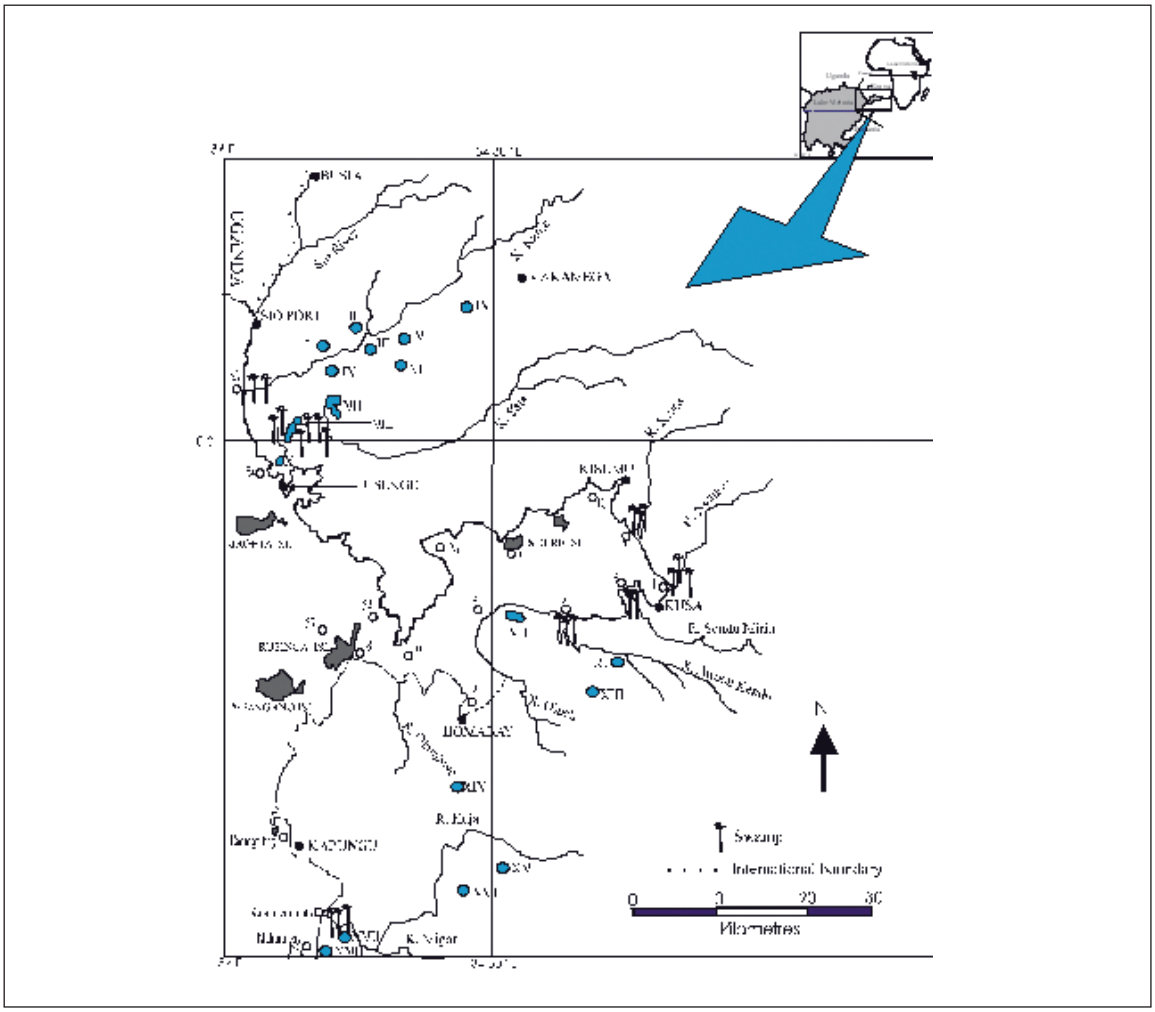

Figure 1: Map of Lake Victoria showing the study sites in the main lake and the location of the SWBs. The SWBs are; I: Mauna, II: Ugege, III: Kalenyjuok, IV: Mwer, V: Ufinya, VI: Ulanda, VII: L. Kanyaboli, VIII: L. Namboyo, IX: Uranga, X: L. Sare, XI: Kosiga, XII: Ulanda, XIV: Mugowa, XV: Stella, XVI: Uriri, XVII: Kokech, XVIII: Olasi (Source Gichuki and others 2004).

Lake Victoria and the small water bodies in Uganda

Approximately 43% of the total lake area lies in Uganda. Major lake systems associated with Ugandan portion of Lake Victoria basin are the Kyoga, Nabugabo and Kooki (Figure 2). Many of these lakes are eutrophic and are relatively shallow compared to Lake Victoria. Lakes Victoria and Kyoga share a common evolutionary history and have similar native fish faunas (Worthington 1929). Both lakes are ichthyo-geographically similar and received Nile perch (*Lates niloticus*) and Nile Tilapia (*Oreochromis niloticus*) introductions in the 1950s. Satellite lakes surrounding Lake Victoria include: Wamala, Kachera, Mburo, Nabugabo, Kayanja and Kayugi. Those constituting the Kyoga system are lakes Nawampasa, Nyaguo, Agu, Gigate, Lemwa and Kawi (Figure 2). Lakes Kachera, Mburo, Kijanebalola and Nakivali are referred to as the Kooki lakes. The Kooki lakes are located in an extensive swamp fed by River Ruizi, and exited by River Kibali, which discharges into Sango Bay, Lake Victoria. Most satellite lakes are isolated from each other and from their main lakes by swamps. Many of the satellite lakes, especially, those associated with Lake Kyoga harbour stocks of endemic fish species, which are rare or extinct from Lake Victoria.

Figure 2: Map showing Lake Victoria and associated satellite lakes in Uganda (Source Gichuki and others 2004)

Lake Victoria and its small satellite water bodies (SWB) in Tanzania

The Lake Victoria drainage basin on the Tanzanian part covers an area of 115,380 km^2, which is about 51 % of the total lake area. The Kagera region in the West, Mwanza and part of Shinyanga regions in the South and Mara region in the East are part of the lake's catchment (Figure 3). Small satellite water bodies in this portion of the Lake Victoria basin include lakes Burigi, Ikimba and Malimbe and rivers Kagera, Mara, Simiyu, Rubana, Suguti and Mori (Figure 3). The lakes and wetlands systems comprise those of the lower Kagera complex (lakes Rusha, Kalenge, Katwe, Ikimba, Bugiri, Rwakajunju and Ngoma), the Masirori swamp (Lake Kubigena), and the Kirumi ponds. Major rivers draining into Lake Victoria are Mara, Mori, Suguti, Grumet, Simiyu, Rubana, Suguti, Ngono, Magogo, Mbalageti, Moame and Kagera. Kagera and Mara rivers originate from Rwanda and Kenya respectively.

The Tanzanian SWBs are shallow with maximum depth in the range 1.8 m to 8 m. One commonality of these lakes is the presence of extensive macrophytes mostly *papyrus* along their shorelines. Lake Burigi is 7,000 ha in area and is linked to river Kagera and Lake Victoria through an extensive wetland drained by River Mwisa. Half of the lake area falls within the National Park, and this has strongly influenced sustainability of fish diversity. Lake Ikimba has a surface area of 12,500 ha., and is also connected with Lake Victoria through river Mwisa. Together with Lake Malimbe, these lakes (Burigi, Ikimba and Malimbe) contain high fish diversity. The lakes are important refugia to the endangered fish species of Lake Victoria. They share the floral and faunal composition with Lake Victoria. The dense cover of macrophytes surrounding these lakes makes it difficult to access.

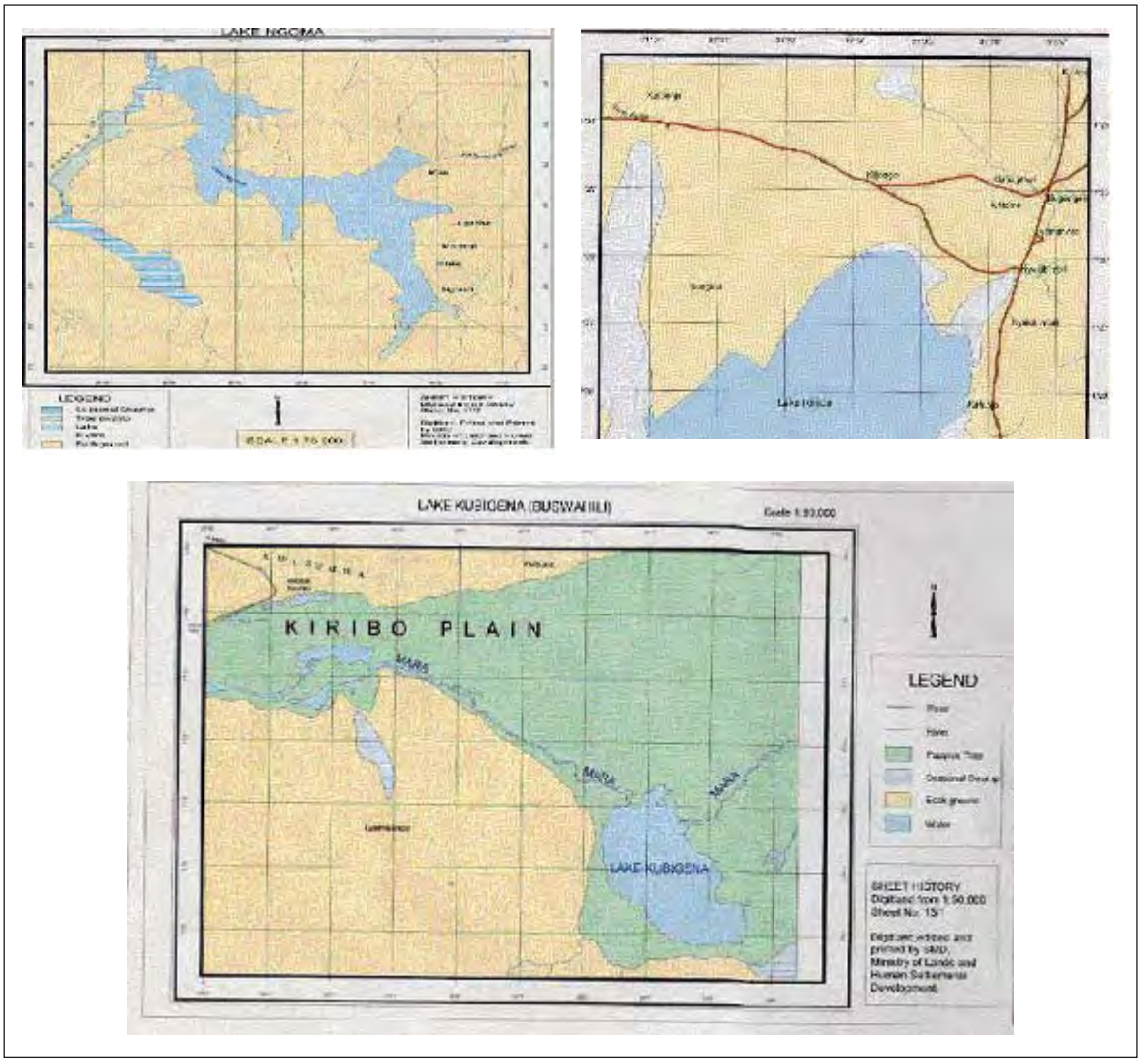

Figure 3: Map showing small water bodies in the Tanzanian part of the Lake Victoria basin (Source Gichuki and others 2004).

Algal Communities in the Lake Victoria basin

General floristic survey of African lakes begun at the turn of the nineteenth century (Schmidle 1898, 1902; West 1907; Woloszynska 1914), and initial phytoplankton samples from Lake Victoria were collected by Stuhlmann in 1892 (Crul 1995). Different African lakes have thus received variable attention since the 1940s and up to the present day. Detailed classical records of algal species are those of Evans (1962a 1962b) and Talling (1965 1966), while those for algal primary productivity are Talling (1957a, 1957b) and Talling & Talling (1965). These records are a benchmark for rating changes in algal composition and productivity over the time. Later studies on this flora were stimulated by interests on pollution, conservation of biodiversity and the drastic loss of fish species in Lake Victoria (Talling 1987; Ochumba & Kibaara 1989; Hecky 1993; Hecky and others 1994; Mugidde 1993; Komarec & Kling 1991; Lehman & Branstrator 1993; Lehman 1998). About five hundred infrageneric taxa in over one hundred genera of algae have been described for the African great lakes (Cocquyt and others 1993; Cocquyt & Vyverman 1994). Diatoms are of especial paleo-ecological significance (Richardson and others 1978; Kilham & Kilham 1989) in these lakes.

The combined effects of chemical, physical and hydrological factors largely determine the algal communities in aquatic systems. Consequently, the ecological integrity of several of the East African lakes has been altered as a result of simultaneous changes in their physical, chemical and biological

properties. These changes have had impacts on the quality and quantity of algae, especially in Lake Victoria (Akiyama and others 1977; Hecky 1993; Hecky and others 1996; Lehman and others 1998; Lung'ayia and others 2000; Kling and others 2001; Mugidde 2001). Diatom community is now dominated by *Nitzschia spp* as opposed to *Aulacoseira* (*Melosira*) and *Cyclostephanos* that made up to 70%-99% of the biomass of the 1960s (Talling 1957a 1957b; Evans 1962a, 1962b; Kling and others 2001). A wide variety of cyanobacteria (blue-green algae) that were consistently low in the 1960s now appear more frequently and filamentous heterocystous cyanobacteria such as *Cylindospermopsis* make up a large fraction of the algal community of the lake. Green algae also occur in very low abundance with some taxa, e.g., Desmids having disappeared. Larger chlorophytes such as *Pediastrum* are rare. Phytoplankton biomass (chlorophyll *a*) has increased 6-fold since the 1960s (Talling 1966, 1987; Mugidde 1992, 1993; Kling and others 2001) following the general increases in phosphorus (P) and nitrogen (N) loading in the lake (Hecky 1993; Lipiatou and others 1996; Ogutu-Ohwayo 1992; Lehman and others 1998). Global warming, climate change, and species introductions are believed to be the driving forces behind the phytoplankton blooms and driving domination by cyanobacteria. Fish species introductions enhanced changes in algal species composition through the trophic cascading. Note that following the introductions (of Nile Perch *Lates niloticus* and Nile Tilapia *Oreochromis niloticus*), the endemic detritivorous and phytoplanktivorous haplochromine and tilapiine cichlids (*Oreochromis variabilis, O. esculentus* and *O. leucostictus*) got displaced and disappeared from the lake (Goldschmidt and others 1993; Ogutu-Ohwayo 1992).

Algae and fisheries

Algae play an important role in the productivity of Lake Victoria and the small water bodies in the lake basin. They form the main part of phytoplankton in the open waters, whereas, in the littoral zone, algae are important in the benthos. Algae and macrophytes (*Azolla*, papyrus, and water hyacinth) are the major primary producers and the source of food in the Lake Victoria ecosystems. Several microalgae species such as *Oscillatoria, Microcystis, Aulacoseira*, *Nitszchia, Melosira* and *Pediastrum* are frequently encountered in the food items of detritivorous and phytoplanktivorous cichlids in Lake Victoria.

Excessive algal proliferation (algal blooms) may cause death to a number of aquatic animals either from lack of oxygen (at night) or from toxins (Boney 1975). Reports exist on massive fish kills in Lake Victoria. For example, in the 1990s, massive fish kills were observed in the Nyanza Gulf and attributed to the effects of the then cyanobacteria blooms (Ochumba 1990). Cyanobacteria, especially *Microcystis* occur in high abundances in Lake Victoria and some of the SWBs.

Phytoplankton groups

There are 344 species in 140 genera and 8 phyla of phytoplankton in Lake Victoria and SWBs (Table 1). The eight phyla are Cyanophyta, Chlorophyta, Bacillariophyta, Dinophyta, Euglenophyta, Pyrrophyta, Chrysophyta and Cryptophyta. Bacillariophyta (diatoms) are the most diverse with 111 species on the Kenya side of the lake (Table 1). Cyanophyta (cyanobacteria or blue-green algae) are well represented in the SWBs. They often constitute between 60 to 97% of individuals (cells or filaments) in the main Lake Victoria and the SWBs. The most abundant planktonic genus found in most water bodies is *Microcystis*. *Cylindrospermopsis* is a common cyanobacterium that occurs almost throughout the year.

Microcystis aeruginosa, M. flos-aquae, Anabaena circinalis and *A. circularis* are the most abundant cyanophytes in the inshore waters of Lake Victoria (especially in Nyanza, Mwanza and Napoleon Gulfs, and in the bays). Filamentous cyanobacteria are often abundant in the littoral zone and on rocky shores where they form an important part of the biomass. Solitary filamentous cyanobacteria, e.g., *Planktolyngbya*, *Anabaena, Pseudoanabaena*, and *Anabaenopsis* species are also common in the plankton. Non-mucilaginous green algae: *Scenedesmus*, *Ankistrodesmus, Coelastrum* and *Cosmarium* spp are associated with shallow nutrient-rich waters and are among the most common green algae in all the lakes. The diatom, *Nitzschia,* especially *N. acicularis,* dominates the phytoplankton in the open waters of Lake Victoria though are often overtaken by cyanobacteria during non-mixing periods. *Nitzschia* is also common in most of the SWBs. Members of Euglenophyta such as *Euglena*, *Phacus* and *Trichelomonas* are well distributed in many of the shallower SWBs.

Table 1: Numbers of algal species belonging to different phyla in the various water bodies (Source: Lungáyia and others 2004).

Taxa/ Water body	Victoria-Uganda	Victoria-Kenya	Victoria-Tanzania	Kachera	Mburo	Kayanja	Kayugi	Nabugabo	Gigati	Kawi	Agu	Nyaguo	Lemwa	Nakuwa	Nawambasa	Wamala	Victoria Nile	Ulanda	Mauna	Ufinya	Kalenjuok	Nyamboyo	Uranga	Ugege	Mwer	Sare	Kanyaboli	Kosiga	Kokech	Oyombe	Migowa	Olasi	Uriri	Stella	Simbi	Katwe	Mara	Kirumi	Malimbe	Burigi/Butiama	Ikimba	Buswahili	Kyarano
Cynophyta	29	31	20	17	26	10	9	9	27	28	14	39	32	23	19	24	26	3	5	5	3	3	1	4	3	3	4	2	5	5	1	3	2	2	5	20	9	11	17	11	12	2	3
Chlorophyta	25	21	26	19	23	11	11	20	15	15	14	20	23	12	4	18	22	4	1	2	3	6	6	3	3	0	3	1	4	3	3	1	2	1	5	23	7	14	20	15	10	4	7
Bacillariophyta	9	111	15	5	5	2	2	1	7	7	2	4	8	4	3	8	14	5	2	4	1	0	3	3	2	1	3	5	2	0	0	0	3	2	0	9	8	8	3	7	4	10	7
Dinophyta	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1
Euglenophyta	2	5	2	3	1	2	1	3	1	2	0	2	2	1	1	5	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	1	1	2	1
Pyrrophyta	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysophyta	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0
Cryptophyta	1	0	0	1	1	1	1	1	1	1	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Total number of taxa	**67**	**169**	**72**	**47**	**56**	**26**	**24**	**34**	**51**	**53**	**30**	**65**	**65**	**41**	**27**	**58**	**69**	**13**	**9**	**11**	**7**	**9**	**10**	**12**	**8**	**5**	**10**	**9**	**11**	**8**	**4**	**4**	**7**	**6**	**10**	**55**	**26**	**37**	**43**	**35**	**28**	**18**	**19**

Abbreviations used are given in brackets: Lake Victoria - Uganda (Victoria-Uganda, Vic-U), Lake Victoria - Kenya (Victoria-Kenya, Vic-K), Lake Victoria - Tanzania (Victoria-Tanzania, Vic-T), Kachera (Kra), Mburo (Mbr), Kayanja (Kja), Kayugi (Kgi), Nabugabo (Nbo), Gigati (Ggt), Kawi (Kwi), Agu (Agu), Nyaguo (Ngo), Lemwa (Lmw), Nakuwa (Nwa), Nawambasa (Nsa), Wamala (Wla), Victoria Nile (V.le), Ulanda (Ula), Mauna (Mau), Ufinya (Ufi), Kalenjuok (Kal), Nyamboyo (Nya), Uranga (Ura), Ugege (Uge), Mwer (Mwe), Sare (Sar), Kanyaboli (Kan), Kosiga (Kos), Kokech (Kos), Kokech (Kok), Oyombe (Oyo), Migowa (Mig), Olasi (Ola), Uriri (Uri), Stella (Ste), Simbi (Sim), Katwe (Kat), Mara (Mar), Kirumi (Kir), Malimbe (Mal), Burigi/Butiama (Bur), Ikimba (Iki), Buswahili (Bus), Kyarano (Kya).

The algal species composition of Lake Victoria is comparable to that in the SWBs. Many of the species are widely distributed in the different water bodies (Tables 1,2) although a few are rare and are reported in only one or a few water bodies. Some species were found in some of the SWBs but were not recorded in the main lake during the surveys and vice versa.

Table 2: The most widely distributed phytoplankton species in Lake Victoria and its satellite small water bodies. (Source: Lungáyia and others 2004).

Species	Number of water bodies where present	Species	Number of water bodies where present
Anabaena circinalis	15	Anksitrodesmus falcatus	20
Anabaena flos-aque	13	*Cosmarium* sp.	23
Anabaenopsis sp.	19	Pediastrum simplex	17
Aphanocapsa sp.	23	Pediastrum tetras	14
Chroococcus sp.	19	Scenedesmus acuminatus	19
Cylindrospermopsis africana	13	Scenedesmus arcuatus	21
Merismopedia elagans	12	Scenedesmus quadricauda	26
Merismopedia tenuissima	27	*Scenedesmus* sp.	15
Microcystis aeruginosa	31	*Stuarastrum* sp.	15
Microcystis flos-aquae	17	Tetraedron trigonum	18
Microcystis sp.	13	*Cyclotella* sp.	19
Planktolyngbya circumcreta	22	*Fragilaria* sp.	15
Planktolyngbya contorta	14	*Nitzschia* sp.	15
Planktolyngbya sp.	22	*Phacus* sp.	13

Macrophytes Communities in the Lake Victoria basin

Macrophytes are higher plants that grow in aquatic ecosystems and whose processes and characteristics are largely controlled by water. They can be subdivided into four major groups on the basis of their water requirements, life forms and habitats:

- Submerged macrophytes are completely covered under water and rooted in the substrate. These macrophytes have thin finely dissected leaves adapted for rapid exchange of nutrients with water. Examples include *Ceratophyllum demersum* and *Najas horrida*.
- Floating leafed macrophytes are rooted but have their leaves floating on the water surface. *Nymphaea lotus* and *Trapa natans* are good examples of floating leafed macrophytes.
- Free-floating macrophytes are a group of water plants that float on the water surface. Such plants have buoyancy and are adapted to drift on the water surface. Under this category are found *Eichornia crassipes* and *Pistia stratioptes*.
- Emergent macrophytes. These are rooted plants with their principal photosynthetic surfaces projecting above the water. Notable examples include *Phragmites australis* and *Typha domingensis*.

Establishment, distribution and diversity of macrophytes

It is believed that haplochromines used to protect the inshore areas of the lake from the establishment of macrophytes by constantly disturbing the substrate (Witte and others 1992a). The heavy rains of 1961-1964 caused a 2m rise in lake levels and destroyed most aquatic plants especially floating leafed and submerged macrophytes in the littorals. Deforestation of the catchment and the resultant elevated soil erosion and heavy siltation of river mouths and shores of the lake, have lately contributed to extensive macrophyte establishment. Macrophytes in Lake Victoria occur mainly in the vicinity of river mouths. As riverbeds widen, the water current is reduced and begin to deposit silt. These are easily colonised by emergent macrophytes and form swamps.

Factors that influence the establishment and distribution of macrophytes include: depth, topography, type of substrate, and exposure to currents/winds and water turbidity. The distribution of macrophytes is also often related to their method of attachment (Sculthorpe 1976). Macrophytes may be dispersed through river currents. Birds also play a role in dispersal of seeds, spores and asexual propagules. Man is responsible for macrophyte dispersal through fishing nets. In the Lake Victoria basin, areas with muddy substrates, especially river mouths, have higher densities and diversity of macrophytes compared to rocky and sandy substrates.

The two free-floating macrophytes on Lake Victoria: *Pistia stratiotes* (the water cabbage) and *Eichornia crassipes* (the water hyacinth) are exotic. The latter is believed to have originated from Rwanda and Burundi through River Kagera. The weed was first spotted in Lake Victoria in the late 1980s. The only free floating plants in the lake before the invasion by water hyacinth were *Pistia stratiotes, Azolla pinnata* and *A. nilotica.* On the establishment of water hyacinth, in mid 1990s, the weed smothered and pushed *Pistia stratiotes* and the *Azolla* spp out of the water. The increased debris in proximity to land due to the dense water hyacinth mats encouraged proliferation of *Vossia cuspidata* and *Echinochloa haploclada* communities, leading to total displacement of *Pistia stratiotes* and the *Azolla* spp. The latter has since disappeared from the Kenyan portion of the lake.

Other communities that were decimated by water hyacinth included *Nymphaea lotus*, *Ceratophyllum demersum*, *Najas horrida* and *Trapa natans*. The successful control and subsequent successions have however resulted in the re-emergence of some of the endemic flora. This cycle is expected to continue so long as the biological control agents continue to suppress proliferations of water hyacinth in the lake. Small water bodies in Lake Victoria basin are refuge to some unique macrophytes not found in the main lake. Such plants include *Ottelia ulvifolia* and *Nymphoides brevipedicellata* while those unique to the lake are *Vallisneria spiralis* and *Trapa natans*.

Zonation pattern of macrophytes

Macrophytes normally establish in succession of zones between the dry land and water, each zone being dominated by specific plant species. Jensen (1977) demonstrated that lakes can be characterized by the type of vegetation observed along transects for those areas not influenced by in-flowing or out-flowing rivers, as these tend to have luxuriant vegetation. Variation in zonation pattern depend on hydrology and may also be affected by ecological succession where a plant community alters environmental conditions in a way that makes the habitat less favourable for its own survival but more favourable for the development of another community. In a typical macrophyte zonation in Lake Victoria, free-floating plants normally occupy the lake ward open water zone (Figure 4). During some seasons, this zone may also be occupied by floating islands consisting mainly of the emergents *Cyperus papyrus* and *Vossia cuspidate.* These however, eventually sink to the bottom or drift out to the shores. Behind the open water zone follows floating leafed and submerged macrophytes. Emergent macrophytes occupy the zone next to land. In this zone are *Vossia cuspidata*, *C. papyrus*, *Hibiscus* spp and many climbers like *Ipomoea aquatica* and *I. rubens*. Behind the shoreline zone are usually water tolerant grasses, sedges, shrubs and trees. The latter, of which *Acacia elaphroxylon* is an example, is more common around the main lake while the small water bodies are dominated by other *Acacia* spp.

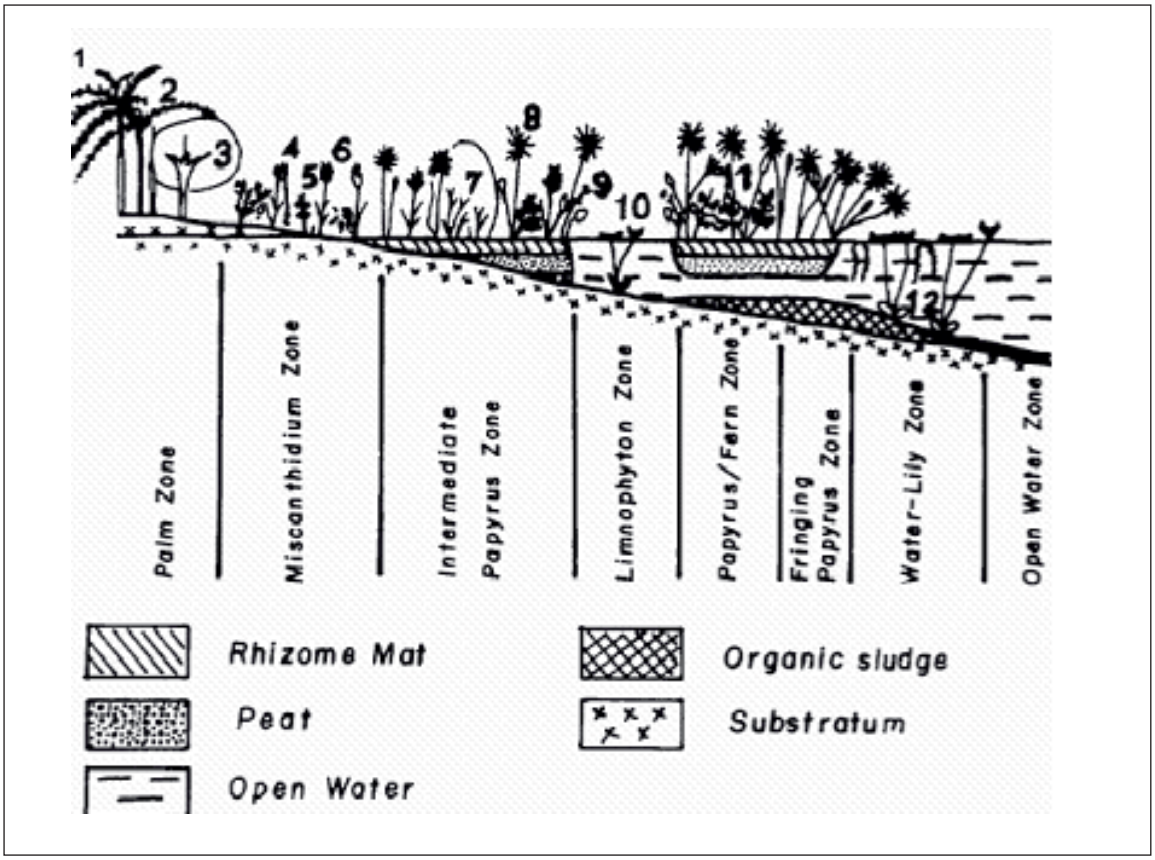

Figure 4: Typical zonation of macrophytes in the Lake Victoria basin. The species represented are: (1) *Phoenix reclinata* (2) *Raphia monbuttorum* (3) *Mitragyna stipulosa*. (4) *Sphagnum* spp. (5) *Dissotis brazzei* and *Leersia hexandra*. (6) *Miscanthidium Violaceum*. (7) *Ficus verruculosa*. (8) *Cyperus papyrus*. (9) *Limnophyton obtusifolium*. (10) *Trapa natans*. (11) *Dryopteris striata*. (12) *Ceratophyllum demersum, Utricularia i*nflexa and *Potamogeton* schweinfurthii (From Thompson 1976 cited in Lyaruu, and others 2004).

Ecological importance of macrophytes

Ecologically, macrophytes constitute one of the most important plant communities found in Lake Victoria. Macrophytes are regarded as the most productive plant communities in the world (Penfound 1956; Reddy 1984; Westlake 1963). They are also known to be the cradles of biological diversity, providing water and primary productivity upon which countless species of plants and animals depend for survival (Chapman and others 2001). Besides forming the base of the varied type of food chains, food webs, energy flow patterns and energy pyramids, the aquatic vegetation exerts a much more profound influence upon the ecosystem of which it is a part, than does the terrestrial vegetation. They act as the physical substrate for periphyton and insects thus providing a positive benefit to the ecosystem, facilitating overall food chain production as well as contributing to primary production. Macrophytes provide surfaces for egg incubation and *refugia* for juvenile fish (Kaul and others 1971). Recent studies have shown that the encroachment of the shores and beaches by water hyacinth has resulted in the re-appearance and subsequent increase of some fish species that were reportedly on the decline or threatened with extinction (Odongkara 1997; Njiru and others 2002). Wide coverage of water hyacinth provided protection of the breeding and nursery grounds that were vulnerable to poor and destructive fishing methods. Macrophytes are known to support a wide array of fish diversity and form important breeding grounds of both fish and avifauna.

Macrophytes act as efficient filters of excessive nutrients from the catchments, which could otherwise lead to eutrophication in the lake. Although the absorption may not in itself ensure the removal as the plants might re-release them on decomposition, the wet, low oxygen soils favour denitrification by bacteria leading to loss of nutrients (Gaudet 1976). In some cases, species of macrophytes such as

Eichornia crassipes are known to have the capability of absorbing high amounts of heavy metals that result from industrial effluents and domestic sewage. Macrophytes, especially emergents, form buffers around water bodies where they intercept silt and protect the shorelines from wave action. These plants also help in conservation of the water bodies by controlling indiscriminate utilization.

Socio-economic importance of macrophytes

The communities around the lake have utilized macrophytes from the basin for various purposes (Table 3).

Table 3: Economic importance of some macrophytes in Lake Victoria basin (Source: Lyaruu, and others 2004).

Scientific name	Local names	Uses
Cyperus papyrus	Matende, Togo	Construction, medicinal
Nymphaea capensis	Malenda, Yunga	Medicinal
Phragmites mauritianus	Matete, Odundu	Construction
Pistia stratiotes	Vinete, Anyuongi	Medicinal, mulching
Sesbania sesban	Marugume, Osaosao	Construction, firewood and fodder
Vossia cuspidata	Etezi, Saka,	Fodder
Luffa cylindrica	Dodoki, Spanj	Medicinal
Thelypteris totta	Ebingara	Animal food, soil binder
Aeschynomene elaphroxylon	Mizira, Ambach, Orindi	Construction
Eichornia crassipes	Gugu maji	Fodder, manure, ornamental
Cyperus digitatus	Ndago, saka	Fodder
Ceratophyllum dermesum	Marwenge	Medicinal
Trapa natans	Sikio la tembo, Ndaali	Medicinal
Echinochloa scabra	Saka, Nasakagazi	Fodder
Commelina benghalensis	Odielo	Fodder
Vernonia glabra	Olusia	Medicinal
Typha capensis	Mahuhi, Odhong'	Construction
Ipomoea cairica	Selele	Fodder

Problems associated with macrophytes

Less than 20 of the 700 species of macrophytes are considered weeds (Triest 1993). As a consequence of their prolific growth and production, macrophytes often interfere with human utilization of water bodies in a number of ways. Recent findings indicate that apart from interfering with fishing and navigation, free-floating mats of macrophytes are a threat to biological diversity affecting fish and other fauna, plant diversity, and food chains (Garry and others 1997).

In Lake Victoria, water hyacinth proliferation interferes with navigation and fishing activities. Small boats are not able to penetrate through the mats, while their engines get clogged with submerged macrophytes. Fishing gear, especially gill nets, are frequently destroyed by the floating islands. The latter also destroy spawning and nursery grounds by scraping the substrate in the shallow areas. Macrophytes in Lake Victoria basin also play host to a number of disease vectors including snails and mosquitoes (for Bilharzias and Malaria, respectively).

Zooplankton communities in the Lake Victoria basin

Zooplankton communities in the Victoria basin are mostly crustaceans, of which the key groups are copepods and cladocerans or water fleas (Plate 1). Non-crustacean zooplankton includes rotifers and the semi-benthonic insect larvae of *Chaoborus* spp.

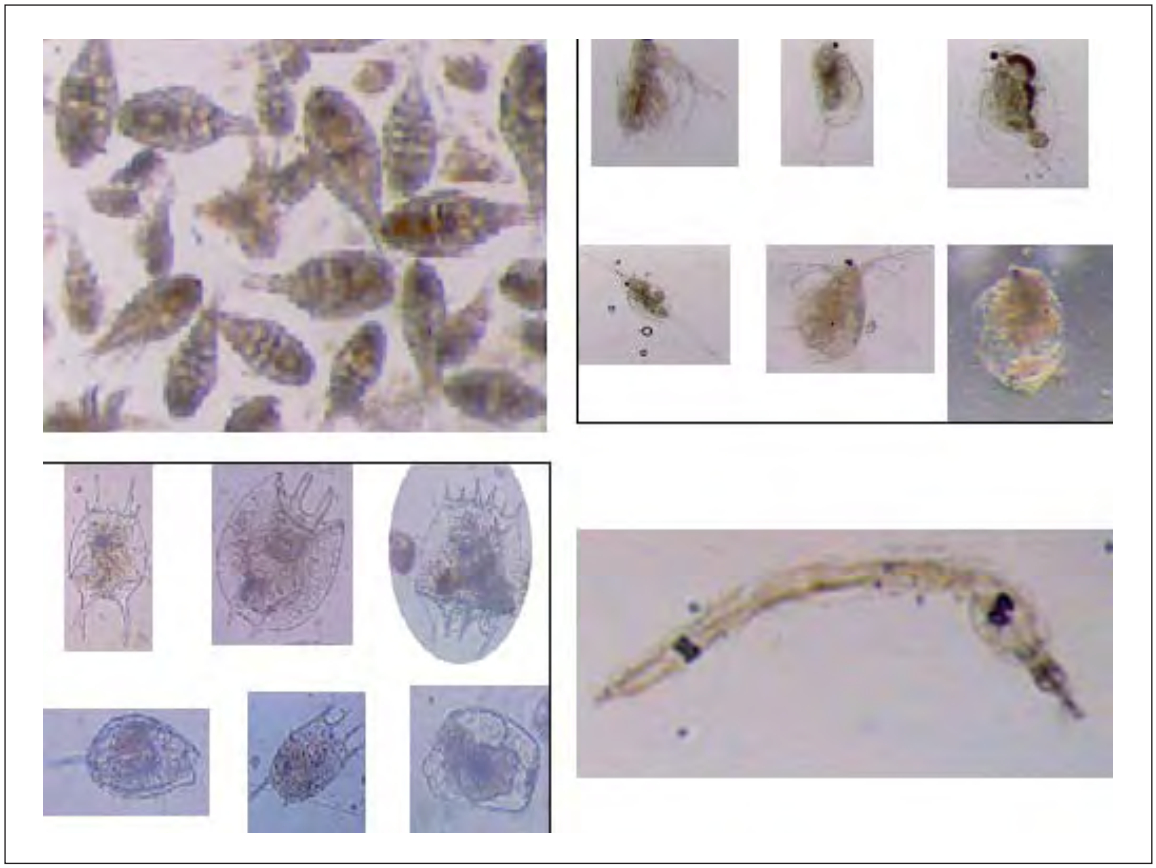

Plate 1: Top left: Copepoda; Top right: Cladocera; Bottom left: Rotifera; Bottom right: *Chaoborus* larva (Source: Mwebaza-Ndawula and others 2004).

The chaoborids stay in or near bottom sediments during daytime but ascend into the water column by night. Also the semi-benthonic freshwater prawns, *Caridina nilotica* Roux are commonly encountered in the plankton of Lake Victoria especially in samples taken at night owing to diurnal migratory behaviour similar to that of chaoborid larvae. Occasionally, water mites (Hydracarina) and ostracods also occur in the plankton. Pioneer studies on zooplankton communities in Lake Victoria were carried out through the expeditions of the early twentieth century (Daday 1907; Sars 1909; Delachaux 1917; Worthington 1931). These studies were largely descriptive and restricted to the shallow sheltered bays, gulfs and channels of the lake, and they provide a basis for tracking community changes by comparison with present-day investigations (Akiyama and others 1977; Mavuti & Litterick 1991; Mwebaza-Ndawula 1994 1998; Branstrator and others 1996).

Zooplankton community of Lake Victoria

The zooplankton community of Lake Victoria is made up of three broad taxonomic groupings: Copepoda, Cladocera and Rotifera. Other groups of minor importance are: the dipteran larvae and the acarid mites. The Zooplankton species composition is almost uniform over the lake (Table 4). Among cyclopoid copepods for example, 6 of the 8 species are common to the three portions of the lake (Kenya, Tanzania, and Uganda). The only two exceptions are: *Thermocyclops oblongatus* Sars, missing from Tanzania waters, and *Thermocyclops decipiens* Kiefer not encountered in Ugandan and Tanzanian waters. The two-calanoid species (*T. galeboides* Sars and *T. stuhlmanni* Mrazek) are widely distributed over the lake. Seven of the 10 Cladocera species occur in all three portions, as *Daphnia barbata* is only found in the Kenya portion, while *Chydorus sphaericus O.F.M.* and *Alona* sp. are not encountered in the Tanzania waters. A total of 16 rotiferan species out of 24 are distributed lake wide. The remaining 8 species are missing in the southern portion of the lake (except *Platyias patulus*, which is also not encountered in the Ugandan records).

Table 4: A Checklist of zooplankton species composition in the Kenyan, Ugandan and southern portion of Lake Victoria (P = present; A= not encountered). (Source: Mwebaza-Ndawula and others 2004).

Taxa	Kenya	Southern portion	Uganda	Taxa	Kenya	Southern portion	Uganda
Crustaceans				*B. calyciflorus* Gosse	P	P	P
Cyclopoida				*B. caudatus* Ahstrom	P	P	P
Thermocyclops neglectus Sars	P	P	P	*B. patulus* Muller	A	A	P
T.emini Mrazek	P	P	P	*B. falcatus* O.F. Muller	P	P	P
T. incisus Kiefer	P	P	P	*Filinia longiseta* Zacharias	P	P	P
T. oblongatus Sars	P	A	P	*F. opliensis* Zacharias	P	P	P
T. decipiens Kiefer	P	A	A	*Keratella cochlearis* Gosse	P	P	P
Mesocyclops spp.	P	P	P	K.quadrata	P	P	P
Tropocyclops confinnis Kiefer	P	P	P	*K. tropica* Apstein	P	P	P
T. tenellus Sars	P	P	P	*Polyarthra vulgaris* Carlin	P	P	P
Calanoida				Sychaeta sp.	P	P	P
Thermodiaptomus galeboides Sars	P	P	P	Lecane spp.	P	P	P
Tropodiaptomus stuhlmanni Mrazek	P	P	P	Monostyla sp.	P	A	P
Cladocera				Collotheca sp.	P	A	P
Daphnia lumholtzi Sars (hemeted)	P	P	P	*Asplanchna brightwelli* Gosse	P	P	P
D. lumholtzi var.monacha	P	P	P	*Ascomorpha* sp.	P	P	P
D. longispina Leydg	P	P	P	*Trichocerca cylindrica* Imhof	P	P	P
D. barbata	P	A	A	Aneuropsis sp.	P	A	P
***Ceriodaphnia cornuta* Sars**	P	P	P	Epiphanes	P	A	P
Diaphanosoma excisum Sars	P	P	P	Euclanis sp.	P	P	P
Bosmina longirostris O.F.M.	P	P	P	Hexathra mira	P	A	P
Chydorus sphaericum O.F.M	P	A	P	Platyias patulus	P	A	A
Alona sp.	P	A	P	Pompholyx sp.	P	A	P
Moina micrura Kurtz	P	P	P	Insecta			
Decapoda				*Chaoborus* larvae/pupae	P	P	P
Caridina nilotica Roux	P	P	P	Arachnida			
Non-crustaceans: Rotifera				Acarid mites	A	A	P
Brachionus angularis Gosse	P	P	P				

Copepods, represented by Cyclopoida and Calanoida (adults and their life cycle instars: copepodites and nauplius larvae) dominate the zooplankton community of Lake Victoria. Field investigations carried out over the period 2000-2002 in Kenya, Uganda and the southern portion of the lake showed that over 80% of the community is constituted by cyclopoid copepods (Fig. 5). Cyclopoida were abundant at both shallow inshore waters as well as deep open areas. On the other hand calanoid copepods contributed much smaller numerical proportions except in the offshore areas of the southern waters where a relatively high level of abundance (39.5%) was encountered. Rotifers, which were common and abundant at inshore sites, diminished to very small proportions in offshore waters of the lake. Cladocera highest numerical abundance occurred in the Kenya section with 7-8% compared to 1-3% in the southern portion and Uganda sections of the lake. Corresponding biomass data for shallow inshore areas and deep offshore waters in Uganda portion of the lake confirm the dominance of cyclopoid copepods (Figure 5) in the zooplankton community.

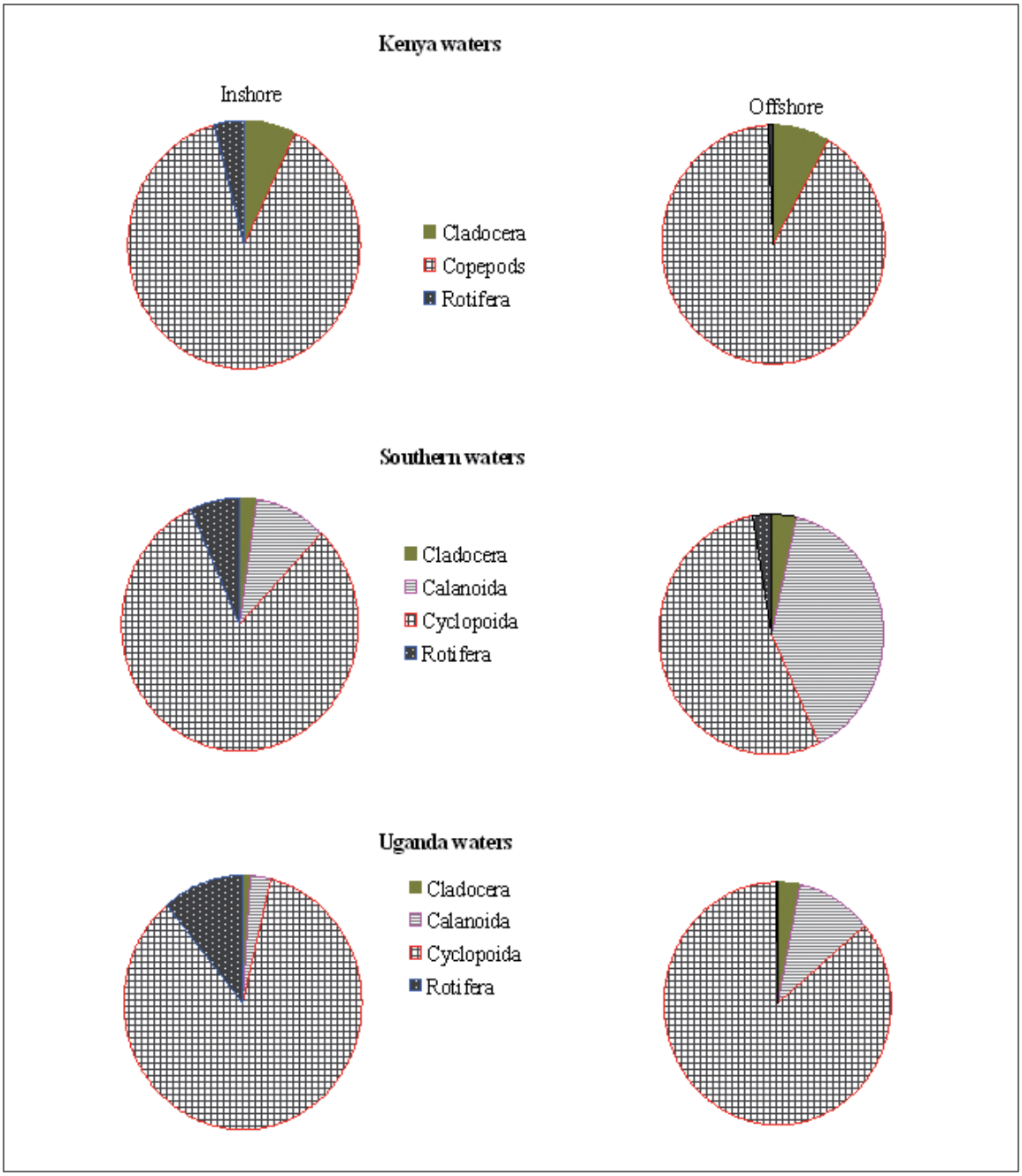

Figure 5: Relative abundance of different zooplankton taxa at selected locations in the Kenya, Uganda and southern portion of Lake Victoria 2000-2002. (Source: Mwebaza-Ndawula and others 2004).

Zooplankton communities of small water bodies in the Victoria basin

The zooplankton communities of the small water bodies in the Kenyan, Ugandan and southern sections of the Victoria basin are similar in that they are composed of the same crustacean taxa i.e. Cladocera and Copepoda; and non-crustacean Rotifera (Tables 5, 6, & 7). At species level, *Diaphanosoma excisum* and *Chydorus* sp. have global distribution in the basin. Data in the tables below present some of the observable regional and local differences in distribution of Zooplankton species. Zooplankton species richness varied widely between water bodies in the Victoria basin area. Kenya basin small water bodies gave an extreme example where only 2 species were recorded in Mwer dam compared to 14 in Lake Kanyaboli. In the Ugandan and southern basin area species richness was much higher (range: 17-32 and 17-23 respectively) and inter-lake variation in species richness was much lower compared to the Kenya section (Tables 5, 6 & 7).

Ecological and economic role of zooplankton communities

The ecological role of the zooplankton community in Lake Victoria has been presented and discussed by Mavuti & Litterick (1991). As one of the major primary consumers, zooplankton converts algal production into animal material for use by fish and other organisms further up in the food chain. In Lake Victoria, zooplankton is an important food source for all fish larvae. As a result, the survival of fish larvae and eventual recruitment of fish into the fishery is largely dependent on zooplankton availability. Trophic relationships between zooplankton and fishes have shown the importance of certain taxa as key forage items for commercially valuable fishes such as *R. argentea*, *O. niloticus* and larval *Lates niloticus*. *R. argentea* derives over 70% of its food requirements from copepods (particularly cyclopoid copepods), which constitute the commonest and most abundant group in Lake Victoria (Mwebaza-Ndawula 1998). Fish larvae prefer the small-bodied rotifers, which are abundant around shallow inshore areas of the lake.

Juveniles of the commercially important Nile perch, *Lates niloticus* Linne feed largely on the semi-planktonic freshwater prawn, *Caridina nilotica* (Ogutu-Ohwayo 1990; Ogari & Dadzie 1988). Adult Nile perch is indirectly dependent on zooplankton through feeding on the zooplanktivorous *Rastrineobola argentea* Pellegrin and pelagic haplochromines. Zooplankton also constitutes important forage for carnivorous invertebrates such as *Mesocyclops* spp. (cyclopoid copepod) and *Chaoborus* sp. (midge larva), which are in turn important food for fish (Irvine & Waya 1995). Zooplankton community is therefore a major link in energy flow integrating carnivorous invertebrates and pelagic fishes for production of major commercial fishes such as the Nile perch. Worldwide, zooplankton is known to affect phytoplankton populations through grazing, which in turn influence water quality and fish production. In the tropical Lake Victoria however, Lehman & Branstrator (1994) found no significant impact of zooplankton grazing on algae.

Table 5: Occurrence and distribution of zooplankton species/taxa in small water bodies in the Kenyan portion of the Victoria basin (Source: Mwebaza-Ndawula and others 2004).

Taxa	Water body							
	Uranga dam	Ugege dam	Ulanda dam	Mwer dam	Mauna dam	Ufinya dam	Lake Sare	Lake Kanyaboli
CLADOCERA								
Diaphanosoma excisum	A	P	P	A	P	P	A	A
Daphnia *lumholtzi*	A	A	A	A	A	A	P	P
Chydorus sp.	A	A	A	A	P	A	A	A
Alona karua	A	A	A	A		P	A	A
Macrothrix sp.	A	A	A	A	A	P	A	A
COPEPODA								
Cyclopoida	P	P	P	P	P	P	P	P
Calanoida	A	A	A	A	A	A	P	P
ROTIFERA								
Keratela tropica	P	P	P	P	P	A	P	P
Brachionus angularis	A	A	P	A	A	A	P	P
B. plicatilis	P	A	A	A	A	A	A	A
B. caudatus	P	A	A	A	A	A	A	A
Aneuropsis spp	A	A	A	A	A	A	A	P
Epiphanes spp.	A	A	A	A	A	A	A	P
Asplanchna	P	A	A	A	A	A	A	P
Trichorcerca	P	A	A	A	A	A	A	P
Proales spp.	A	A	A	A	A	A	A	P
Synchaeta sp.	A	A	A	A	A	A	A	P
Polyarthra spp	P	A	A	A	A	A	A	P
Total number of species/taxa	**7**	**3**	**4**	**2**	**4**	**4**	**5**	**14**

Table 6: Occurrence and distribution of zooplankton species/taxa in small water bodies in the southern portion of the Victoria basin,. P = present, A = not encountered, helm = helmeted (Source: Mwebaza-Ndawula and others 2004).

Taxa	Water body							
	Lake Kyaramo	Lake Kubigena	Kirumi Pond	River Mara	Lake Katwe	Lake Ikimba	Lake Malimbe	Lake Burigi
CLADOCERA								
Bosmina longirostris	A	P	A	A	A	P	A	A
Ceriodaphnia cornuta	P	A	P	A	P	A	A	P
Daphnia lumholtzi (helm.)	P	P	P	P	A	A	A	P
Diaphanosoma excisum	P	P	P	P	A	A	A	P
Moina micrura	A	P	P	P	P	A	P	P
Chydoruss sp.	P	A	A	A	P	A	A	A
Alona sp.	A	A	P	A	P	A	A	A
COPEPODA								
Calanoida								
Thermodiaptomus galeboides	P	A	A	A		A	A	A
Cyclopoida								
Thermocyclops emini	P	P	P	P	P	P	P	P
Thermocyclops incisus	P	P	A	A	P	P	A	A
Thermocyclops neglectus	P	P	P	P	P	P	P	P
Tropocyclops confinnis	A	A	A	P	P	P	P	P
Tropocyclops tenellus	P	A	P	P	P	P	P	P
ROTIFERA								
Ascomorpha sp.	A	A	P	P	P	P	A	P
Asplanchna spp.	P	P	P	P	P	P	P	A
Brachionus angularis	P	P	P	P	P	P	P	P
Brachionus calyciflorus	P	A	P	P	P	A	P	P
Brachionus caudatus	A	P	P	P	A	P	P	P
Brachionus falcatus	P	A	A	P	A	A	A	A
B. patulus	A	A	A	P	P	A	A	A
Kellicotia sp.	A	A	A	A	A	P	A	A
Euclanis sp	A	P	A	P	A	A	P	A
Filinia longiseta	A	A	A	A	A	A	P	A
Filinia opoliensis	P	P	A	P	P	A	P	P
Keratella cochlearis	P	P	P	A	P	P	P	P
Keratella tropica	P	P	P	P	P	P	A	P
Keratella quadrata	A	A	A	A	P	P	A	P
Lecane spp	P	P	A	P	P	P	P	P
Polyarthra vulgaris.	A	A	A	A	P	P	A	A
Synchaeta spp.	P	P	P	P	P	P	P	A
Trichocerca cylindrical	A	A	A	A	P	P	P	A
Trichocerca spp.	P	P	A	P	P	A	A	A
Total number of species/taxa	**19**	**17**	**16**	**20**	**23**	**18**	**16**	**17**

Table 7: Occurrence and distribution of zooplankton taxa in small water bodies in the Ugandan portion of the Victoria basin. P = present, A = not encountered. (Source: Mwebaza-Ndawula and others 2004).

Taxa	Water body						
	Lake Kayanja	Lake Kayugi	Lake Nabugabo	Lake Kachera	Lake Mburo	Lake Wamala	Kabaka's lake
CLADOCERA							
Bosmina longirostris	A	A	P	A	A	P	A
Ceriodaphnia cornuta	A	A	P	P	A	P	A
Chydorus spp.	A	A	A	A	A	P	A
Diaphanosoma excisum	A	P	P	A	A	P	P
Moina micrura	P	P	P	P	P	P	P
Macrothrix sp.	P	A	P	A	P	P	P
COPEPODA							
Harpacticoida	A	A	P	A	A	A	A
Cyclopoida							
Eucyclops spp.	A	A	P	P	A	A	A
Mesocyclops spp.	P		P	P	P	P	
Thermocyclops emini	A	A	A	A	P	P	A
T.incisus	P			P		P	P
T.neglectus	P	P	P	P		P	P
T.decipiens	A	A	A	A	A	P	A
T . tenellus	A	A	P	A	A	A	A
ROTIFERA							
Ascomorpha spp.	A	A	A	A	A	P	A
Asplanchna spp.	P	P	P	P	A	P	P
Brachionus angularis	P	P	P	P	P	P	P
B.bidentatus	A	A	P	P	A	P	A
B.budapestinensis	A	A	P	P	P	P	P
B.quadridentatus	A	A	A	A	A	P	A
B.calyciflorus	P	P	P	P	P	P	P
B.falcatus	P	P	P	P	P	P	P
B.patulus	A	A	A	P	A	A	A
Brachionus spp.	A	A	A	A	P	A	A
Euclanis spp.	A	A	A	A	P	P	A
Filinia longiseta	P	P	P	P	P	P	P
F.opoliensis	P	P	P	P	P	P	P
Hexathra spp.	P	P	P	P	P	P	A
Keratella cochlearis	P	P	P	A	A	P	P
K.tropica	P	P	P	P	P	P	P
Lecane bulla	P	P	P	P	P	P	A
Polyarthra spp.	A	P	P		P	P	A
Polyarthra vulgaris.	P	P	P	P	P	P	P
Synchaeta pectinata	A	A	P	P	A	P	P
Synchaeta spp.	P	P	P	P	P	P	P
Trichocerca cylindrical	P	P	P	P	P	P	P
Trichocerca spp.	A	A	P	A	P	P	P
Total number of species	**18**	**17**	**28**	**22**	**20**	**32**	**19**

Macroinvertebrates communities of the Lake Victoria basin

Aquatic macroinvertebrates are macroscopic fauna without a backbone (vertebra), visible to unaided eye, and retained by a standard sieve of mesh size 0.5-0.6 mm (APHA 1985; Reddy & Rao 1991; Wiederholm 1980). The group is distinguished from Meiofauna whose size range is 0.25 to 0.4 mm; and from zooplankton, which are free-floating in open or pelagic waters. Also commonly referred to as Macrofauna and/or Macrobenthos, they include flatworms, roundworms, annelids, molluscs, echinoderms and macrocrustaceans. They are mostly found attached to the substratum under water. Since they are almost always close to, on, or in the bottom substrate, they also are collectively referred to as benthos. Those living close to or in association with water plants are also described as phytofauna. None the less, though macrofauna live at particular environment within a water body (on rock surfaces, in gravel, on sand, on roots, on stems or on leaves; as the case may be), it does not mean that they are restricted to this environment. Most of them migrate from one habitat to another. Their descriptive names are therefore not fixed for any group, but on the basis of where they were located at the time of sampling. For example, *Chaoborus spp* and *Caridina nilotica* Roux undergo diel vertical migration within the water column. Some macroinvertebrates live in both aquatic and terrestrial environments depending on the stage of development in their life history. Lepidoptera (moth), Ephemeroptera (Mayfly), Odonata (dragonfly) and Plecoptera (stonefly) during larval and nymphs stage live in aquatic environment but live on land as adults. Some species have even more complex life cycles. Insect groups for example, Coleoptera (adults and larvae) and Hemiptera (instars and adults) contribute to the diversity in aquatic environments (Muli 2003).

Communities of macro-invertebrates are under threat in many water bodies from environment degradation, especially eutrophication and pollution. These threats may cause alterations in species composition, distribution and abundance patterns and ultimately community structure, which affect their ecological functions. In their different forms of existence, these organisms contribute to the well being of their habitats either as prey or predator. It is therefore important to study the status of aquatic macroinvertebrates as a basis to understanding their ecological values including contribution to fishery production.

Economic importance of aquatic macroinvertebrates in the Lake Victoria basin

Aquatic macroinvertebrates have manifold benefits. The water beetles of the family Curculionidae, *Neochetina Eichorniae* Warner and *Neochetina bruchi* Hustache have been successfully used to control the noxious Water hyacinth (*Eichornia crassipes* (Mart.) Solms.) worldwide. The swamp worm *Alma emini* (Michaelsen) is harvested for fish bait around Lake Victoria (Muli & Mavuti 2001). Some communities in Lake Victoria basin consume Lakeflies (Macdonald 1953). *Caridina nilotica* and mollusc shells are commercially exploited in some parts of Lake Victoria, processed and incorporated into domestic animal feeds.

Benthos are cheaper and better indicators for assessing and monitoring water quality in lakes and rivers. The biotic indices such the Belgian Biotic Index (BBI), Biological Monitoring Working Party-score (BMWP) and Trent Biotic Index (TBI) are some examples of the biological assessment methods in use in Europe (Premazzi & Chiaudani 1992). Because they have long life, are a constant presence, sedentary, comparatively large sized, and they endure external stress, benthos can integrate changes in the habitat over time, which can be used to interpret characteristic changes in the sediment and the water column (Wielderholm 1980; Reddy & Rao 1991).

Though most other species do not have direct economic uses, their contribution to the functioning of the ecosystem cannot be underestimated. A number of mollusc species found in the lake basin are vectors of diseases of man, livestock and wildlife such as Schistosomiasis, Fascioliasis and Paramphistomiasis. Mollusc vectors commonly occurring in Lake Victoria basin include species of the genera *Lymnaea, Bulinus* and *Biomphalaria*. Other benthos that are vectors of human diseases are mosquito larvae (*Anopheles, Aedes* and *Culex* genera) known to transmit Malaria, Yellow fever and Filariasis among others (Muli and others 2000). Ceratopogonidae (biting midges) suck blood and can be a pest locally (Rzóska & Lewis 1976). Lakeflies (again) do not carry disease but can be a nuisance. Leeches and

argulids are parasitic on other aquatic organisms, e.g. fish (Mbahinzireki 1977). The mayfly *Povilla adusta* Navás (Ephemeroptera) is a well-known woodborer and its larvae can cause serious damage to wooden structures beneath the waterline (Corbet 1957).

Ecological role of macroinverterbrates in the ecosystem

Macroinvertebrates promote primary production and nutrient recycling. According to Mwebaza-Ndawula (1990), the role of detritus feeding organisms including benthos and *Caridina nilotica* Roux is of particular importance in the regeneration of soluble nutrients from the bottom sediments in Lake Victoria. *Caridina* promotes photosynthetic production of submerged plants through detritus consumption and subsequent exposure of their leaf surfaces to light. Molluscs secrete sulphuric acid in their digestive process and this is an essential nutrient to the water promoting primary productivity (Fish 1956).

Macroinverterbrates play a crucial role in conversion of plant material into animal protein for use by other organisms including various fish species, which depend on invertebrates for food. Gastropods and bivalves, for example, are important prey for the lungfish *Protopterus aethiopicus* (Heckel) (Mosile 1988); chironomid and chaoborid larvae are important in the diet of most demersal (bottom-dwelling) fishes such as the *Ningu* (*Labeo victorianus* (Boulenger) and elephant snout fish, *Mormyrus kannume* (Forsskal). The freshwater prawn, *Caridina nilotica*, Mayfly (Ephemeroptera) and Dragonfly (Odonata) nymphs constitute the food for juvenile Nile perch, *Lates niloticus* (Ogutu-Ohwayo 1984). Macro-invertebrates therefore play an important role in aquatic food chains, bridging between algal primary production and the higher trophic levels. Many phytoplanktivorous insect larvae and molluscs (gastropods and bivalves) form the basis of secondary production in the lake (Macdonald 1956; Corbet 1961; Greenwood 1966; Witte and others 1995a,b).

Diversity and distribution of macroinvertebrates in Lake Victoria basin

The benthic fauna of Lake Victoria is dominated by molluscs (ca. 44%), insect larvae and nymphs (ca. 41%). Oligochaetes, leeches, nematodes, ostracods and other crustaceans are also present though in minor proportions (Figure 6). A total of 66 benthic macroinvertebrate species have been recorded in Lake Victoria (Tables 8a and 8b). These include 28 species of molluscs, 26 species of insects, 5 species of crustaceans and 5 species of oligochaetes. The Kenya portion of Lake Victoria has the highest number of taxa (62) compared to 26 and 22 for the Uganda and Tanzania portions of the lake respectively.

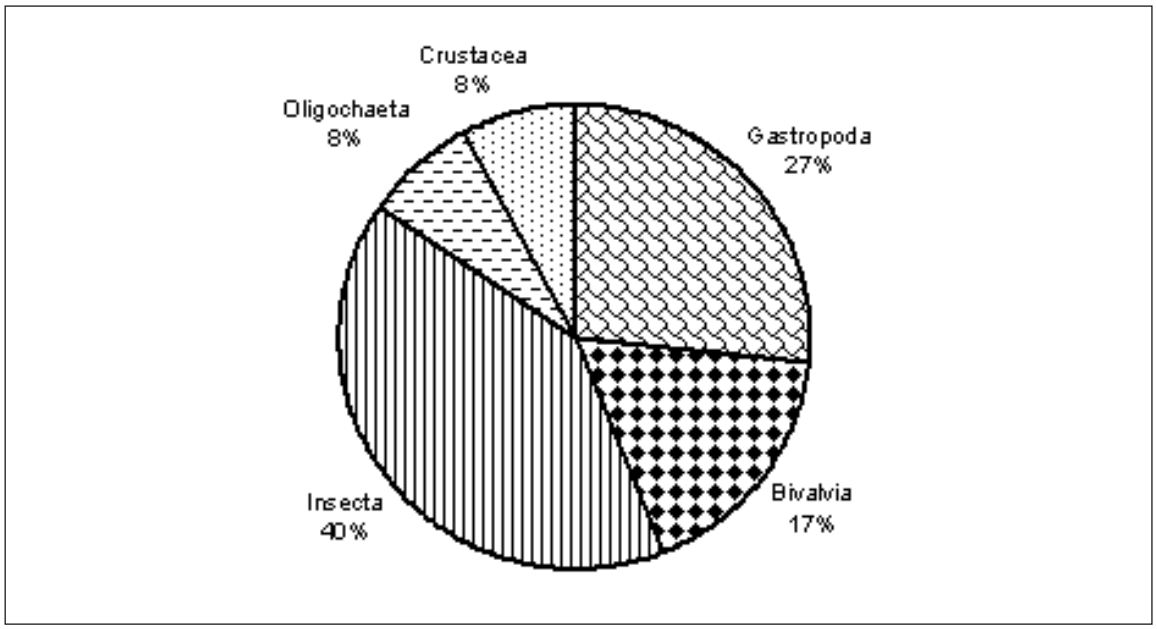

Figure 6: Composition of major benthic macroinvertebrates groups in Lake Victoria (1990-2003).

(Source: Muli and others 2004).

Table 8a: List of benthic mollusca and Annelida taxa recorded in Lake Victoria (P-present). Adapted with modification from Okedi (1990), Mbahinzireki (1994), Muli and Mavuti (2001) and Mwambungu (2003).

(Source: Muli and others 2004).

Taxa	Kenya	Tanzania	Uganda	Taxa	Kenya	Tanzania	Uganda
GASTROPODA				Sphaerium victoriae	P		
Viviparidae				Eupera ferruginea	P	P	
Bellamya unicolor	P	P	P	Mutelidae			
Bellamya constricta		P		Mutela bourguiguati	P	P	P
Pila ovata gordon (Smith)	P	P		Mutela dubia	P		
Pila ovata nyanzae (Smith)	P	P		*Aspatharia* spp.	P	P	
Thiridae				Unionidae			
Melanoides tuberculata	P	P	P	*Cafferia caffra* (Krauss)	P		
Cleopatra guillemei Bourguignat	P	P		Caelatura hauttecouri	P	P	P
Cleopatra bulimoidae		P		Caelatura monceti	P	P	
Bithyniidae				Caelatura alluandi		P	
Gabbiela humerosa (Martens)	P	P	P	Corbiculidae			
Planorbidae				Corbicula fluminalis africana	P	P	P
Biomphalaria spp.	P	P		**OLIGOCHAETA**			P
Biomphalaria choanomphala (Martens)	P	P		Tubificidae			
Bulinus spp. Müller	P			Branchiura sowerbyii	P		
Bulinus globosus (Morelet)	P	P	P	*Limnodrilus* spp. Claparède	P		
Bulinus ugandae				*Tubifex* spp.	P		
Bulinus truncatus trigonus (Martens)	P	P		Haplotaxidae	P	P	
Ancylidae				Lumbriculus variegates		P	
Ferrissia clessiana Jickeli	P			Glossoscoleidae			
Ferrissia kavirondica Mandahl-Barth	P			Alma emini	P	P	
BIVALVIA				**HIRUDINEA**	P	P	P
Sphaeriidae							
Sphaerium nyanzae	P	P					
Sphaerium stuhlmauni	P	P					

Table 8b: List of benthic non-mollusca taxa recorded in Lake Victoria (P-present). Adapted with modification from Okedi (1990), Mbahinzireki (1994), Muli and Mavuti (2001) and Mwambungu (2003). (Source: Muli and others 2004)

Species	Kenya	Tanzania	Uganda	Species	Kenya	Tanzania	Uganda
INSECTA				Baetidae			
HEMIPTERA				*Baetis* spp. Leach	P	P	P
Corixidae		P	P	ODONATA			
Micronecta spp. Leach	P			Libellulidae	P	P	P
Stenocorixa spp.	P			*Pantala* spp.	P		
Sigara spp.	P	P		*Somatochlora* spp. Selys	P		
Notonectidae		P	P	Macromiidae			
Anisops spp.	P			*Macromia* spp. Rambur	P		
Plea spp.	P			*Didymops* spp. Rambur	P		
Notonecta spp.	P			Gomphidae		P	P
Belostomatidae				*Aphylla* spp.	P		
Lethocerus niloticus	P			TRICHOPTERA			P
Hydrocyrius spp.	P			Polycentropodidae	P	P	
DIPTERA				Leptoceridae	P		
Chaoborus spp.	P	P	P	Pschomyiidae	P		

Chironomus formasipennis	P	P		CRUSTACEA			
Chironomidae	P	P	P	Potamonidae	P		
Tanyodinae	P	P	P	Potamonautes spp.	P		
Heleidae	P			Atyidae	P		
Procladius brevipetiolatus	P			*Caridina nilotica* Roux	P	P	P
Tanypus gullatipennis	P			Chydoridae	P		
EPHEMEROPTERA				*Chydorus* spp. Leach	P		
Polymitarcidae				Ostracoda	P		P
Povilla adusta	P	P	P	Conchostraca			P
Caenidae							
Caenis spp. Stephens	P	P	P				

Molluscs are globally distributed in most major habitats of lake. For example, the group constituted 50 – 94 % in abundance of macroinvertebrates at the Mara, Yala, and Sondu river mouths; and in Mwanza gulf, Speke gulf, Asembo bay, and Kisumu bay. Gastropoda of the families Viviparidae and Planorbidae, and particularly the two species: *Melanoides tuberculata* (Müller) and *Bellamya unicolor* (Olivier) are the most represented and abundant of the molluscs. These two gastropods are widely distributed over the major habitats of the lake. For example, the densities of *M. tuberculata* are highest in the Winam gulf and the mouth of River Yala compared to the open waters. On the other hand, *Bellamya unicolor* is most abundant at the Mara mouth, in Speke gulf and Mwanza gulf. Though rare, the ancylids *Ferrissia clessiniana* (Jickeli) and *Ferrissia kavirondica* Mandahl-Barth*,* are found in appreciable quantities in the Winam gulf between the Yacht Club and Dunga (Brown 1994; Muli & Mavuti 2001). The Schistosomiasis vectors: *Bulinus globosus* (Morelet), *Bulinus ugandae* and *Biomphalaria choanomphala* (Martens) are also rare.

The most speciose Bivalvia families in the lake are Sphaeriidae, Mutelidae and Unionidae (Table 8a). In Kenya waters, Bivalvia is dominated in abundance by three species, *Caelatura hauttecouri, Mutela* spp., *Corbicula fluminalis africana* and *Sphaerium nyanzae* Smith in that order of increasing dominance in both the Winam gulf and main lake. Oligochaetes are ubiquitous in occurrence in most habitats of the lake where in most cases their abundance is less than 6% of the total benthic abundance. In some areas such as Entebbe and Namirembe bays the abundance is slightly elevated ranging between 13 and 28 %. Areas near the mouths of rivers Kasat, Kibos and Nzoia and in open deep waters (ca. 40 m), off the Nyanza Gulf had very high densities of this group dominated by tubificids *Limnodrilus* spp. Claparède, *Tubifex* spp. *Branchiura sowerbyii* Beddard and *Alma emini* (Michaelsen).

Insecta consists mainly of hemipterans and dipterans. Other major taxa in order of decreasing species richness were Odonata, Ephemeroptera and Trichoptera. Insects tend to dominate (> 75%) in abundance in areas where mollusks and oligochaetes are scarce such as northern Lake Victoria in Uganda and the Kagera region in Tanzania. The abundant species are the larvae and nymph of aquatic insects belonging to the families Chironomidae and Orders Ephemeroptera, Odonata and Trichoptera. The dominant species are *Chaoborus* spp. Lichtenstein*, Chironomus formasipennis, Procladius brevipetiolatus, Tanypus gullatipennis* (Chironomidae), *Povilla adusta* Navás (Ephemeroptera) and *Libellula* spp. Linné (Odonata). The other insect species are very rare. The swimming insects include hemipteran imagoes and nymphs of *Micronecta* spp.*, Sigara* spp. Fabricius (Corixidae), *Anisops* spp. (Notonectidae) and *Lethocerus niloticus* (Belostomatidae). Larvae of Chironomidae and Chaoboridae are represented in all major habitats of the lake. They are the most abundant benthic fauna in northern Lake Victoria, Uganda (Mbahinzireki 1994) and in Kagera region in Tanzania. The other orders are confined to particular habitats of the lake. For example, ephemeropterans are confined to mouths of Rivers Sondu/Miriu and Yala. Larvae and pupae of Trichoptera are confined in Winam gulf and Namirembe bay.

Caridina nilotica Roux is widely distributed in the lake and constitutes a major by-catch in *Rastrineobola argentea* (Pellegrin) fishery. Ostracods are common in northern Lake Victoria (Uganda) but are rare in Kenyan waters. They have not been reported in Tanzania waters. Crabs (*Potamonautes* spp.) are also rare though frequently encountered in gillnet fish catches from rocky shores all round the lake. For example, they occur in fishing grounds around Lwanda Gembe in Suba district.

Pelagic macroinvertebrates of Lake Victoria

The common macroinvertebrates in the water column of Lake Victoria are the fresh water prawn *Caridina nilotica* Roux, larval and pupae stages of chaoborids, chironomids and corixids and water mites (Mavuti & Litterick 1991). These macrofauna are not restricted to the water column, but do migrate to different regions within lake. They occur in both littoral and pelagic regions as well as the profundal.

Benthos of satellite lakes and dams in the catchment of Lake Victoria

Satellite lakes of Lake Victoria are considered important because they are natural museums of Lake Victoria. Lakes Kanyaboli, Sare and Namboyo have been described as the “Lake Victoria of the 1950s”; because some endemic fish species, which are known to have disappeared from Lake Victoria, occur abundantly in these lakes. These lakes have in fact been proposed as national parks to preserve their rich biota (Muli 1998). A number of studies have been documented benthos on these lakes, e.g., Abila (1995) on Lake Kanyaboli; Muli (2001) on Lakes Sare, Kanyaboli and Simbi and in various dams such as: Mauna, Migowa, Ugege, Uranga, Kaleny juok, Mwer, Ulanda, Oyombe, Migowa, Kosiga, Kwambai (Ratanga), Gogo falls, Stella, Kokech and Kobodo; and Mwambungu (2003) on Lakes Katwe, Kirumi, Buringi, Ikimba, Kyarano dam and Mara River. Lakes Mburo, Nabugabo, Kayanja and Kayugi in Uganda, have been studied more extensively since mid 1960’s compared to other satellite lakes. Reports by Corbet (1961) and Greenwood (1966) provide valuable information on fish-macro-invertebrate trophic relationships and therefore their contribution to fishery production in Lake Victoria and other water bodies in the basin. Other studied satellite lakes include Wamala, Lemwa, Kawi, Gigati, Nyaguo, Agu, Bisina, Kachera, Kyoga, Nawampasa and Nakuwa.

The species composition of benthos in satellite lakes and dams is not different from that of Lake Victoria. However, the satellite lakes are characterized by very low species richness and abundance of benthos compared to the Lake Victoria. Differences in the substratum could account for differences in diversity. Lake Victoria has an heterogeneous substratum while satellite lakes and dams have a comparatively homogenous substrata (Muli 2001). Besides this, and especially so in Lake Simbi, high water salinity is also responsible for the low species richness (Brown 1994) as does high predation in other SWBs. This low benthic species richness and abundance implies that the amount of food available to fish is low. It is therefore likely that fish production in these SWBs is relatively low.

Fish Communities of the Lake Victoria basin

Before the introduction and the subsequent establishment of the Nile perch and the Nile tilapia, Lake Victoria had a multi-species fishery dominated by haplochromine cichlids (Kudhongania and Cordone 1974). The lake had a variety of habitats that harboured different fish species adapted to life in those specific habitats. Close to 70 non-haplochromines and over 200 haplochromines had been identified and described from the basin (Greenwood 1966; Greenwood 1981). Through predation, environmental degradation and possibly competition for space, many of these species have been displaced from the lake. It is estimated that over 60% of the haplochromine species have greatly diminished in numbers or been completely eliminated. This loss of diversity has ecological repercussions to the whole lake ecosystem. The food web structure has changed with a number of food resources either not used or are underutilized leading to ecological wastage. Other factors thought to be responsible for ecological changes are the lake morphometry and hydrology. Occasional violent storms for example may cause abrupt mixing of the water column leading to massive fish kills (Ochumba 1990). Although many native non-haplochromine fish species have had their numbers diminished in the main lake, none is extinct from the basin. Likewise, new haplochromine species are being identified from areas that were previously not been exhaustively explored, e.g., the rocky habitats and marginal vegetative areas, probably providing refugia to these species.

Fish Species Diversity

Historical Trends in Fish species Diversity

Before the introduction of Nile Perch and the exotic cichlids in the 1950's, Lake Victoria beamed with a diverse fish population whose main components were: tilapiines, *Oreochromis esculentus* (Graham 1929) and *Oreochromis variabilis* (Boulenger 1906); the lungfish *Protopterus aethiopicus* (Herkell 1851); catfish, *Bagrus docmak* (Forskal 1775) and *Clarias gariepinus* (Burchell 1822); and the cyprinid, *Labeo victorianus* (Boulenger 1901). Haplochromines were the most abundant group constituting about 80% of the demersal fish biomass (Kudhongania & Cordone 1974). There were over 300 haplochromine species, majority of them (more than 99%) endemic to the lake (van Oijen and others 1981; Witte and others 1992). This group occupied all trophic levels and played an important role in the flow of organic matter in the ecosystem. Up to 11 trophic groups of haplochromine cichlids were identified from Mwanza Gulf alone (Witte & van Oijen 1990).

The Lake Victoria fish stocks and the fisheries have undergone remarkable changes over the past 20 years. Signs of overfishing were reported as early as 1970 when catch rates of tilapia dropped from 100 fish per 50m long net (127 mm stretched mesh) to less than 5 fish (Ssentongo 1972). As the stocks of Nile perch increased, the diversity of haplochromines decreased rapidly. The contribution of haplochromines to fish biomass in the lake decreased from 80% to less than 1% within a decade of the 1970s and 1980s (Kudhongania & Cordone 1974; Okaronon and others 1985). Following these drastic shifts in species composition and stocks depletion (Othina & Odera 1996), a number of management measures have been instituted on the lake. Notably among these measures are: the ban on the use beach seine nets and under-sized mesh nets (<127 mm stretched mesh) of 1994, the ban on trawlers in 1996, and the introduction of slot size of 50 – 84 cmTL for Nile perch (of 2002).

Various reasons have been advanced for the loss of fish species in Lake Victoria. Haplochromines, for example, were decimated by the introduced perch, overfishing, and environmental changes (Acere 1988; Ogutu-Ohwayo 1988). The native tilapiines i.e. *Oreochromis esculentus* and *O. variabilis* were displaced through inter-specific species competition for food, space, and mates by the introduced superior breeds of *O. niloticus, Tilapia zillii* (Gervais 1848) *T. rendallii* (Boulenger 1896) and *O. leucostictus* (Trewavas 1933) (Balirwa 1990). Deforestation as a result of fuelwood collection to process Nile perch increased sediment run-off into the lake, which also increased nutrient levels. The nutrients have induced eutrophication and led to proliferation of water hyacinth. The decomposition of the algae and water hyacinth results into depletion of dissolved oxygen thus making much of the water column uninhabitable by cichlid and other aqualife. Eutrophication has also disturbed traditional mating systems, which has also contributed to the decline of cichlid species (Goudswaard & Witte 1985). Extensive cover of the inshore waters with water hyacinth and other macrophytes protected the settling off sediments and decaying plant material from currents wash off, thus encroaching on the nesting grounds for the cichlids.

Current status of Fish Diversity in Lake Victoria basin

Recent surveys have shown some resurgence of species, which were thought to have disappeared. Apart from *Lates niloticus, Oreochromis niloticus* and *Rastrineobola argentea*, which for some time constituted the entire fishery on Lake Victoria, more other species, notably: *Labeo victorianus*, *Schilbe intermedius, Clarias gariepinus, Synodontis victoriae, S. afrofischeri* and a number of *Haplochromines* (Nsinda & Mrosso 1999; Chande & Mhitu 2003) have lately been recovered in appreciable quantities, though in localised catches. The main occupants in satellite lakes are *O. esculentus, O. niloticus, Protopterus aethiopicus* and *C. gariepinus*, while the diversity in the rivers is dominated by *S. intermedius, Lake Victorianus, Synodontis* spp. and *Brycinus* spp. These riverine stocks were highly impacted by pollution, habitat destruction, and over fishing at the river mouths. Included among the important environmental factors that contributed to species losses were: competition for food, space and mate; food availability; habitat choice; predation; parasitism; and symbiosis.

Competition affects fish species diversity through niche overlaps where several species exploit a common guild. This type of competition is readily recognised among the tilapiines and is responsible

for the disappearance of the endemic stocks as *O. niloticus* got established in the lake. The rise in lake levels too, flooded the nesting areas of *O. esculentus* compromising the competitive ability of this population in the lake (Welcomme 1967). Nevertheless, the introduced *O. niloticus* was more robust and superior and therefore readily out competed the rest. *O. niloticus* was originally an herbivore but shifted its food interests to grazing on zooplanktons, and eventually, ended up eating fish larvae (Balirwa 1990; Njiru 2002). The species is presently the dominant tilapiine on the lake.

The young of Nile perch and adult *Rastrineobola argentea* feed on zooplankton resources of the lake. The share the pelagic zone where they graze on the free-swimming zooplankton. *Barbus altianalis*, which mainly feed on gastropod molluscs, has been pushed out of the Nyanza Gulf into the Nyando River where it is restricted to the upper reaches.

Fish Habitat Diversity

Vegetated littoral habitats

Littoral areas of the lake are defined as areas with waters less than 6 metres deep (Witte & van Densen 1995). Shallow inshore habitats with fringing macrophytes are known to provide important refugia to stocks of the native species in lakes Victoria and Kyoga. These areas have higher abundance and greater species richness than the open waters (Brazner 1997). Aquatic vegetation supports numerous epiphytic organisms that comprise food for young tilapia and other herbivorous fish species (Welcomme 1964) making these environment important nursery areas. Papyrus (*Cyperus papyrus)* swamps fringing most of the shores of Lake Victoria provide a special refuge against predation by Nile perch. In Lake Victoria *Oreochromis variabilis* still occurs in inshore habitats with fringing papyrus reeds, *Cyperus papyrus.* Nile perch is sensitive to low-oxygen which delimit their distribution and interaction in these hypoxic habitats (Fish 1956).

Some of the cichlids in Lake Victoria can tolerate extreme low oxygen levels, which permit them to use the structural inshore habitats as refugia. In lakes Nabugabo and Nakuwa where Nile perch was also introduced, most of the haplochromine cichlids live among submerged macrophytes especially water lilies where they are protected from predation by Nile perch. Lake Nawampasa is separated from L. Kyoga by dense macrophytes, which have provided a barrier to Nile perch from this lake. These habitats are however under threat from invasive weeds and drainage of surrounding wetlands for agriculture. Weed mats destroy rooted and floating macrophytes leading to destruction of breeding and nursery grounds. Hyacinth mats also cause localised deoxygenation that has resulted in periodic fish kills. Decaying sunken water hyacinth releases poisonous gases like ammonia and hydrogen sulphide. Drainage and clearance of marginal wetlands for agriculture also destroys these breeding and nursery grounds.

Rocky habitats

Rocky shores and islands are currently the most important refugia for indigenous fishes in lake Victoria. They harbour the highest densities and diversity of the cichlids. These habitats are a dominant feature of the shallow waters in the lake. Their complex spatial structure provides a large number of ecological niches and allows complex food webs to thrive. They also provide protection against predation, for example in Mwanza Gulf the rock-dwelling fish species are reportedly the least affected by Nile perch predation (Witte and others 1992a,b). A number of species critically low in numbers or originally believed to be eliminated from Lake Victoria have been recovered from these habitats. Some examples are: *Paralabidochromis victoriae*, *Xystichromis phytophagus* and *Pyxichromis para-orthostoma* among other haplochromines; and *Oreochromis variabilis* and *Labeo victorianus*.

A completely new group of haplochromines, the rock dwelling Mbipi species have been identified and also many species described (Seehausen 1996; Seehausen and others 1998). More than 170 haplochromine species have been recorded from rocky substrates in the southeastern region of Lake Victoria (Seehausen 1996), while 180 have been recorded from rocky habitats in the northern portion. Some non-cichlids also rely on these habitats. Recent research findings have shown that *Lates niloticus* is a frequent member of the rock-dwelling fish communities. While the juveniles of perch may live

together with other rock dwelling fishes, the adults are often found hovering near these rocky habitats in search of prey.

Pelagic habitat

Due to reduced oxygen concentrations down the water column during periods of stratification, some fish species, better able to withstand the low oxygen levels close to the oxycline than the predator, use this zone as refuge from the predator. Such fish species commonly referred to as “the small pelagics”, include *Rastrineobola argentea*, and the zooplanktivorous haplochromines *Yssichromis laparogramma* and *Y. fusiformis*. Also in the pelagic zone may be found juveniles of the Nile tilapia *Oreochromis esculentus* and the Nile perch *Lates niloticus*. Recent trends in the population of pelagic fishes indicate an overall increase in their stocks lake-wide. Populations of *R. argentea* are believed to have increased tenfold between 1970 and 1990 (Ogutu-Ohwayo 1990; Seehausen and others 1997). Of late, catches of zooplanktivorous haplochromines are matching that of *R. argentea*. The fish species composition listed by locality are presented in Tables 9a – 9d).

Satellite Lakes

Satellite lakes and dams have played an important role in conserving endangered fish species of the Lake Victoria region. They have been referred to as “living museums” of East African ecological history (Mwanja and others 2001). The structural heterogeneity of macrophytes surrounding these lakes has made it difficult to access by fishers and to apply certain fishing methods. This has kept much of the biodiversity intact. Many fish species especially the haplochromines considered to have been eliminated from or whose numbers are dangerously low in the main Lake Victoria are still found in these satellite lakes.

The predatory Nile perch has failed to gain access to many of these lakes. Because of the physical and chemical conditions in some of the lakes, the predator could not survive even when directly introduced by man. Due to the dense underwater macrophytes cover for example in Lake Nawampasa (a lake satellite to Lake Kyoga), oxygen concentrations are too low to support the Nile perch at night although the water is supersaturated with oxygen during the day. Fish communities of most of the satellite lakes are composed of fishes native to Lake Victoria. Among the tilapiines, significant populations of the two native species: *O. variabilis* and *O. esculentus* remain in satellite lakes though completely displaced from the main lake. *O. esculentus* has disappeared from lakes Victoria and Kyoga, but has survived both as native and introduced populations in satellite lakes within the Victoria and Kyoga basins.

Table 9a: Main Satellite Lakes of the Lake Victoria basin and their species of biodiversity importance. (Source: Wandera and others 2004).

Country	Drainage System	Lake	Species of Biodiversity importance
Kenya	Yala System	Kanyaboli	*Oreochromis esculentus* and haplochromines
		Sare	*O. esculentus*, Haplochromines
		Namboyo	*O. esculentus*, Haplochromines
		Mauna Dam	*Oreochromis variabilis*
Tanzania	Mara System	Kubigena	*O. leucostictus, Clarias garepinus, Protopterus*
		Kirumi	Haplochromines, *O. esculentus, O. niloticus, O. variabilis*
	Dam	Kyarano	*Labeo victorianus, O. niloticus*
	Kagera System	Katwe	*O. niloticus, Clarias gariepinus, O. leucostictus*
		Kalenge	Haplochromines, *O. esculentus*
		Rushwa	O. esculentus, haplochromines
		Mitoma	*O. esculentus, Haplochromis*
		Lwakajunju	*O. niloticus, Clarias,* Haplochromines
		Ngoma	*O. niloticus, O. esculentus, O. variabilis,* Haplochromines
	Other systems	Burigi	*O. esculentus, O. niloticus, O. variabilis*
		Ikimba	*O. esculentus, O. niloticus*
Uganda	Koki Lakes	Nakivali	O. esculentus
		Mburo	*O. esculentus*
		Kachera	*O. esculentus*
		Kijanebalola	*O. esculentus*
	Nabugabo System	Nabugabo	*Schilbe intermedius, mormyrids, haplochromines*
		Manywa	*O. esculentus*, haplochromines
		Kayugi	*O. esculentus*, haplochromines
		Kayanja	*O. esculentus*, haplochromines
	Kyoga system	Nawampasa	*O. variabilis, O. esculentus* Haplochromines
		Nakuwa	*Schilbe intermedius & Synodontis victoriae*
		Gigati	*O variabilis*, Haplochromines
		Lemwa	*O. esculentus,* haplochromines
		Kawi	*O. esculentus, O. variabilis,* Haplochromines
		Nyaguo	*O. esculentus*, Haplochromines, *Mormyrus macrocephala*
		Agu	Haplochromines
		Bisina	Haplochromines O. variabilis
		Opeta	*O. variabilis,* Haplochromines

Table 9b: Native non- cichlid fish species in Lake Victoria, Kenya (Source: Wandera and others 2004).

	Sampling station																				
TAXA	Nyando R. mouth	Miriu R. mouth	Awach R. mouth	Gingra rock	Oluch river mouth	Gull shoal	Mbita East	Homa Bay	Kibos R. mouth	17A	Asembo Bay	Maboko Island	Ndere Island	Kopiata	36A	Sikri point	M. Mbili	Kuja	Sio River mouth	Nzoia R. mouth	Yala R. mouth
CLARIIDAE																					
Clarias gariepinus			P		P			P		P	P	P		P	P	P	P				
PROPTERIDAE																					
Protopterus aethiopicus							P	P		P		P	P								
CYPRINIDAE																					
Barbus profundus		P																		P	
Barbus kersteni		P																		P	
Barbus trispilopleura			P					P													
Barbus jacksonii			P					P													
Barbus altianalis					P			P													
Barbus neumayeri					P											P					
Barbus apleurogramma					P															P	
Barbus cercops			P	P	P		P													P	
CHARACIDAE																					
Brycinus sadleri	P	P		P	P			P			P	P	P			P					
B. jacksonii	P	P									P	P									
MORMYRIDAE																					
Mormyrus kannume			P																	P	
Gnathonemus longibarbis			P																	P	
Marcusenius victoriae			P																	P	
BAGRIDAE																					
Bagrus docmac						P															
MASTACEMBELIDAE																					
Afromastacembelus frenatus																	P				

Table 9c: Native non- cichlid fishes in the Tanzanian waters of Lake Victoria (Source: Wandera and others 2004)

Species name	Bulamba	Ramadi	Magu Bay	Bunda hills	Mara Bay	Mori Bay	Bauman Gulf	Luchiri	Chatu Bay	Namirembe	Lubafu Bay	Mwanza Gulf
Clarias gariepinus	P	P	P		P	P	P		P	P		P
Labeo victorianus	P	P									P	P
Proptopterus aethiopicus	P					P	P	P				P
Schilbe intermedius	P	P	P	P		P		P				P
Synodontis afrofischeri								P	P		P	P
Synodontis victoriae									P			P
Brycinus jacksonii												P
Brycinus sadleri	P		P	P	P	P				P		P
Caecomastacembelus frenatus										P		
Mormyrus kannume			P									
Marcusenius victoriae			P									

Table 9d: Native non cichlid fishes recorded from Lake Victoria (Uganda), and Lake Kyoga (Source: Wandera and others 2004).

	Koki lakes		**Nabugabo lakes**		**Kyoga lakes**				**Lake Victoria**			
Fish species	Kachera	Mburo	Kayugi	Kayanja	Nabugabo	Nawampasa	Nakuwa	Bisina	Kyoga	Napoleon	Thruston	Hannington
Afromastacembelus frenatus	-	-	-	-	-	P	-	-	P	P	P	P
Barbus altianalis	-	-	-	-	-	-	-	-	P	-	-	-
Bagrus docmak	-	-	-	-	-	-	-	P	-	-	-	-
Brycinus jacksonii	-	-	-	-	-	-	-	-	-	P	P	P
Barbus kerstenii	-	-	P	P	P	-	-	-	-	-	-	-
Brycinus sadleri	-	-	-	-	P	P	-	P	P	P	P	P
Barbus trispidopluera	-	-	-	-	-	P	-	P	-	-	-	-
Clarias alluaudi	-	-	-	P	-	P	-	P	-	P	P	-
Clarias carsonii	-	-	P	-	-	P	-	-	-	P	-	-
Clarias gariepinus	P	P	-	P	-	P	P	P	P	P	-	-
Clarias liocephalus	P	P	-	-	-	-	-	-	-	-	-	-
Gnathonemus victoriae	-	-	P	P	-	-	P	P	-	-	-	-
Mercusenius grahami	-	-	-	-	-	-	-	-	P	-	-	-
Mormyrus kannume	-	-	-	-	-	-	-	-	-	P	P	-
Mormyrus macrocephalus	-	-	-	-	-	-	P	-	P	-	-	-
Mercusenius macrolepidotus	-	-	-	-	-	-	P	-	P	-	-	-
Protopterus aethiopicus	P	P	-	P	P	P	P	P	P	P	P	P
Petrocephalus catostoma	-	-	P	P	-	-	-	P	-	-	-	-
Synodontis afrofischeri	-	-	-	-	P	P	P	P	P	P	P	-
Schilbe intermedius	-	-	-	-	P	-	P	P	P	-	-	-
Synodontis victorianus	-	-	-	-	-	P	P	P	P	P	P	-

Streams, Rivers and River mouths

Streams and rivers affluent to Lake Victoria contribute about 20% of the water into the lake (NEJLV 2002). Because they flow through farmlands, towns and cities, they transport much of the common pollutants produced from these areas of human activities, loading the lake with heavy metals, agricultural chemicals and silt. They therefore influence physico-chemical characteristics of the lake. At the points of entry into the lake (river mouths) they present a water environment different from the rest of the lake. The river mouths therefore constitute a different habitat type with its constituent assembly of fish species.

Rivers act as breeding grounds for anadromous fish species. Long macrophytes that cover banks of the rivers and streams also avail refuge to many species against their predators. Thus rivers and streams have continued to contain fish species that are otherwise in danger of extinction in the main lake. Drainage into Lake Victoria can be grouped into the Eastern and Western drainage systems. There is no major river system save for the numerous seasonal streams draining into the lake from the southern portion while the Northern section has the outlet through the River Nile. The western drainage forming the largest watershed drains the mountains of Rwanda and Burundi through River Kagera. River Katonga and Rwizi/Kibali in Uganda also constitute part of this system. The Eastern system has rivers originating from the Kenyan highlands. Surveys have shown these rivers and their associated streams as containing a number of native fish species that are of conservation value in the main lake.

Waterfowls of the Lake Victoria basin

Lake Victoria basin is endowed with a variety of wetlands ranging from permanent swamps to highly seasonal (some, very temporal) swamps around open water bodies and along rivers. As transition ecosystems between land and water, wetlands are characterized by high diversity of flora and fauna including waterfowls. Throughout the world, birds are a dominant, conspicuous and diverse component in wetland ecosystems. Out of 1,060 species of birds found in Kenya, 255 (44 families) are reportedly associated with water and aquatic vegetation. Thus the wetlands support approximately 25 % of Kenya's avifauna (Gichuki & Gichuki 1992). A total of 170 bird species have been recorded in association with water and wetlands vegetation within the Lake Victoria basin. In Uganda, Omoding and others (1996) reported 159 bird species in 38 families from 82 wetlands. This number is highest (1113 species) on the Tanzania side. This diversity of water birds reflects the fundamental importance, productivity and wider ecological influence of waters in all biomes (Ormerod & Tyler 1993).

Importance of Water Fowl in the Lake Victoria basin

On a global scale, birds are probably better researched and monitored than any other group of animals or plants, and are thus well placed to indicate the overall health of our environment (Furness and others 1993; Greenwood and others 1995). Status of birds can warn habitat loss and modification and can indicate the likely environmental changes on other organisms. The Marabou storks, Leptoptilos *crumeniferus* were generally confined to the national parks and fish landing sites in the past, but lately, they are common even in major towns. The Yellow-billed Oxpecker *Buphagus africanus* and Red-billed Oxpecker *Buphagus erythrorhyncus* are hardly seen on livestock though are common and quite abundant on wildlife in national parks. The Marabou is attracted to the towns by the refuse indicating poor refuse management in towns while Oxypecker was probably thrown out of business by the acaricides. Birds have thus gained important use as 'flagship' species in conservation efforts.

In the fresh water ecosystems, waterfowls are some of the top predators. An important characteristic of birds is their high mobility (Seys and others 1995). The abundance and distribution of birds usually reflects the status of the lower trophic levels and thus giving an indication of the associated biodiversity. For example, fishers use gulls and terns behaviour to locate productive fishing sites (Seys and others 1995). Lesser flamingos respond to unfavourable food conditions related to changes in availability of water and its chemistry by moving from one saline lake to another thereby acting as biological indicators of environmental change (Gichuki & Gichuki 1992). Birds are also important biological elements of the Lake Victoria ecosystem, by returning nutrients through deposition of their *guano*, a nutrient rich form of urea into the herbivorous food chain and are an important food source for other higher vertebrates.

The list of avifauna in the Lake Victoria basin is presented in Table 10, and the conservation status in Table 11.

Table 10: Species Composition birds sited in the Lake basin. (Source: Boera and others 2004).

		Wetlands of Lake Victoria basin	
Common names	**Species**	**TANZANIA**	**KENYA**
Reed cormorant	*Pharacrocorax africanus*		+
Long tailed cormorant	*Pharacrocorax africanus*		+
White breasted cormorant	*Pharacrocorax carbo*		+
African Darter	*Anhinga melanogaster*		+
Little egret	*Egretta garzetta*	+	+
Great-white egret	*Egretta alba*	+	+
Yellow-billed egret	*Egretta intermedia*	+	+
Cattle egret	*Bubulcus ibis*	+	+
Squacco heron	*Ardea ralloides*	+	+
Goliath heron	*Ardea goliath*		+
Grey heron	*Ardea cinerea*	+	+
Black-headed heron	*Ardea melanocephala*	+	+
White stock	*Ciconia ciconia*		
Abdim's Stork	*Ciconia abdimii*		+
Marabou	*Leptoptilos crumineferus*		
Hamerkop	*Scopus umbretta*		+
Yellow-billed stork	*Mycteria ibis*	+	+
African open-billed stork	*Anastomus lamelligerus*	+	+
Saddle-billed stork	*Ephippiorhynchus senegalensis*		
Hadada ibis	*Bostrychia hagedash*	+	+
Sacred ibis	*Threskiornis aethiopica*	+	+
Glossy ibis	*Plegadis falcinellus*	+	+
African spoonbill	*Platalea alba*	+	+
Egyptian goose	*Alopochen aegypticus*		+
Spur-winged goose	*Plectropterus gambensis*		+
Fulvous tailed whistling ducks	*Dendrocygna bicolour*		+
White-faced whistling duck	*Dendocyna viduata*	+	+
African fish-eagle	*Haliaeetus vocifer*	+	+
African marsh-harrier	*Circus ranivorus*	+	+
Black kite	*Milvus migrans*	+	+
Augur buzzard	*Buteo auguralis*	+	
Black-crake	*Amaurornis flavirostris*	+	+
Common moorhen	*Gallinula chloropus*	+	+
Purple gallinule	*Porphyrio porphyrio*	+	+
Crested crane			+
Grey-crowned crane	*Balearica regulorum*	+	
African Jacana	*Actophilornis Africana*	+	+
Common stilt	*Himantopus himantopus*	+	+
Common pratincole	*Glareola pratincola*	+	+
Ringed plover	*Charadrius hiaticula*	+	+
African wattled lapwing	*Vanellus senegallus*	+	
Long-toed lapwing	*Vanellus crassirostris*	+	

		Wetlands of Lake Victoria basin	
Common names	**Species**	**TANZANIA**	**KENYA**
Spur-winged lapwing	*Vanellus spinosus*	+	
Crowned plover	*Vanellus coronatus*	+	
Little stint	*Caladris minuta*	+	+
Pectoral sandpiper	*Caladris melanotos*	+	
Ruff	*Philomachus pugnax*	+	
Redshank	*Tringa tetanus*	+M	
Green shank	*Tringa nebularia*	+M	+
Wood sandpiper	*Tringa glareola*	+M	+
Common sandpiper	*Actitis hypoleucos*	+M	+
Grey-headed gull	*Larus ridibundus*	+M	+
Herring gull	*Larus argentatus*	+M	+
Hemprich gull	*Gelochelidon nilotica*		+
White winged black terns	*Chlidonias leucopterus*		+
Little tern	*Sterna albifrons*		+
Gull-billed tern	*Gelochelidon nilotica*	+M	+
Namaqua dove	*Oena capensis*	+R	+
African mourning dove	*Streptopelia decipiens*	+R	+
Fischer's lovebird	*Agopornis fischeri*	+R	
Speckled mousebird	*Colius striatus*	+R	+
Grey-headed kingfisher	*Halcyon leucocephala*	+R	
Malachite kingfisher	*Corythornis cristata*	+R	+
Pied kingfisher	*Ceryle rudis*	+R	+
Larks		+R	
Common bulbul	*Pycnonotus barbatus*	+R	+
Cistocals		+R	+
Sunbirds		+R	+
Long-tailed fiscal	*Lanius cabanisi*	+R	+
White-helmet shrike	*Prionops plumata*	+R	+
Pied crow	*Corvus splendens*	+R	+
African drongo	*Dicrurus adsimilis*	+R	+
Superb starling	*Spreo superbus*	+R	
Wattled starling	*Creatophora cinerea*	+R	
Ashy starling	*Cosmopsarus unicolor*	+R	
House sparrow	*Passer domesticus*	+R	+
Chestnut sparrow	*Passer eminibey*	+R	
Black-headed weaver	*Ploceus cucullatus*	+R	+
Viellot's black weaver	*Ploceus nigerrimus*		+
Yellow-backed weaver	*Ploceus melanocephalus*	+R	+
Golden backed weaver	*Ploceus jacksonii*	+R	+
Northern masked weaver	*Ploceus taeniopterus*	+R	
Little weaver	*Ploceus luteolus*	+R	
Cardinal quelea	*Quelea cardinalis*	+R	
Red-billed quelea	*Quelea quelea*	+R	
Zanzibar red bishop	*Ueplectes nigroventris*	+R	
Black-winged red bishop	*Euplectes afer*	+R	
Blue cheeked cordon-bleu	*Uraeginthis angolensis*	+R	

		Wetlands of Lake Victoria basin	
Common names	**Species**	**TANZANIA**	**KENYA**
Common waxbill	*Estrida astrid*	+R	
Pin-tailed whyadah	*Vidua macrroura*	+R	+
Bronze Mannikin	*Lonchura fringilloides*	+R	

Key to abbreviations: R = Resident; M = Migratory

Table 11: The Conservation status of wetland birds of the various wetlands in Kenya and of Mwanza Gulf Tanzania (Source: Boera and others 2004).

				TANZANIA	KENYA
Common names	Species	Habitat	Behaviour	Resident conservation status	Conservation status (IUCN)
Long tailed commorant	*Pharacrocorax africanus*	Swamp	feeding	Rare	abundant
Reed commorant	*Phalacrocorax africanus*	Swamp, estuary	feeding	Rare	abundant
White breasted cormorant	*Pharacrocorax carbo*	Swamp	Feeding, nesting roosting	Common,	abundant
African darter	*Anhinga melanogaster*	Swamp	feeding	Rare	
Cattle egret	*Bulbulcus ibis*	Open beaches and shores	Feeding, breeding	Abundant	
Little egret	*Egretta garzetta*	Open beaches and shores	Feeding, breeding	Abundant	
Yellow- billed egret	Egret *Egretta intermedia*	Open beaches and shores	feeding		
Great egret	*Egretta alba*	floodplain	feeding	Common	
Grey heron	*Ardea melanocephala*	floodplain	feeding		
Black-headed heron	*Ardea melanocephala*	Open beaches and shores	Feeding, breeding, nesting	Anundant	
Goliath heron	*Ardea goliath*	Swamps	feeding	Rare	Vulnerable
Hamerkop	*Scorpus umbretta*	Open beaches and shores	Feeding, breeding,nesting	Common	
Open- billed stork	*Anastomus lamelligerus*	floodplain	feeding	Common	
Abdim's stork	*Ciconia abdimii*	Estuary, floodplain	feeding	Common	
Marabou stork	*Leptoptilos crumineferus*	Open beaches and shores	feeding	Common	
Glossy ibis	*Plegadis falcinelus*	floodplain	feeding	Rare	
Hadada ibis	*Bostrychia hagedash*	floodplain	feeding	Rare	
Sacred ibis	*Threskiornis aethiopicus*	Estuary,floodplain	feeding	Abundant	
Crowned crane	*Balearica regulorum*	Swamp, floodplain	feeding	Common	
Augur buzzard	*Buteo rufofuscus*	Open beaches and shores	feeding	Rare	
Grey kestrel	*Falco ardosiaceus*	Open beaches and shores	feeding	Rare	
Black kite	*Milvus migrans*	Open beaches and shores	Feeding, nesting	Abundant	
African fish eagle	*Haliaeetus vocifer*	Swamp	feeding	Rare	
African jacana	*Actopholornis africanus*	Swamp	Feeding	Common	
Spotted bone curlew	*Burhinus copensis*	Swamp	Roosting	Rare	
Pied kingfishers	*Ceryle rudis*	Open beaches and shores	Nesting and feeding	Abundant	
Malachite kingfisher	*Alcedo cristata*	Estuaries	feeding	Common	
Blue breasted kingfisher	*Halcyon malimbicus*	Estuaries	feeding	Rare	
Brown hooded kingfisher	*Halcyon albiventris*	Estuaries	feeding	Rare	

Conservation needs of birds in aquatic ecosystems

Survival of aquatic birds relies in conservation of feeding, breeding, roosting, loafing, and over-wintering sites. Most water birds forage in the wetlands, which include inshore or littoral areas of the lake, swamps, flooded areas (draw-down zones or floodplains), pools and rivers. Wetland macrophytes (papyrus, reeds, trees, etc) are preferred by many species as nesting, roosting and loafing sites. Therefore proper

management measures need to focus on wetland ecosystems. Since some sites in the Lake Victoria basin aquatic systems fulfil the requirement criteria for the establishment of the Ramsar sites, efforts should be put in place to initiate the establishment of more such sites for effective management of the waterfowl biodiversity.

Other higher vertebrates associated with water and wetlands in the Lake Victoria basin

The Lake Victoria basin is home to several species of amphibians, mammals, and reptiles. Each taxon differs in the extent of dependence on aquatic ecosystems. Some species are specialists and require aquatic ecosystems for most of the basic needs during the course of their life. This group usually comes into contact with water for relatively longer periods year round, either for breeding, feeding, or refuge purposes. Other species are generalists or visitors and use aquatic ecosystems occasionally for getting certain basic needs. They use the vegetation part of the aquatic ecosystem for shelter, feeding, or breeding. They also utilise water mainly for drinking, swimming across from one end to another or for leisure.

Factors influencing diversity of higher vertebrates

Size and extension of the littoral zone, macro and microhabitats available for the different aquatic fauna and the extension of wetlands are the main determinants of amphibian, reptilian and mammalian habitation. Most amphibians, for example, are not completely independent of aquatic environments because they must at one time (during breeding and early stages of growth) return to water.

Species richness of higher vertebrates in the Lake Victoria basin

A total of 31 amphibians, 28 reptilian and 44 mammalian species have been recorded from various sites in Lake Victoria basin. Members of the genus *Xenopus* are the only purely aquatic amphibians. They only move from one wetland or water body to another following prolonged rains when the soils become water logged. This group prefers living in slow flowing vegetated streams or ponds with permanent water. Most other species can be said to be semi-aquatic.

The inshore waters and fringing wetlands support several species of reptiles, the commonest of which are the Nile crocodile (*Crocodylus niloticus* Laurent 1768), monitor lizard (*Varanus niloticus* Linnaeus 1766), and snakes such as the African rock python (*Python sebae* Gmelin 1789), mambas, and cobras (Pitman 1974; Chisara and others 2001).

The majority of mammals recorded in the basin are generalists and visit non-aquatic habitats (e.g. forests, shrubs, reeds, sedges) of wetlands for foraging or shelter. Flooding patterns of the aquatic ecosystems controls their presence. Many mammals leave for relatively drier areas during heavy rains. Few species are well adapted to aquatic environment for feeding and breeding purposes. Mammals that largely depend on aquatic environment in their life include Hippos (*Hippopotamus amphibius*) and Spotted-Necked Otter (*Lutra maculicollis*). The Sitatunga (*Tragelaphus spekei*) is a wetland endemic species, which is highly adapted to wading on wetland vegetation and swimming in water.

Specific diversity on selected study sites of the Lake Victoria basin in Uganda

Six major diversity sites, namely LakeVictoria, Kooki lakes - Mburo and Kachera, Lake Wamala, Lake Nabugabo and River Nile are reported. A total of 27 amphibian, 18 reptilian and 40 mammalian species have been recorded in the sites. Lake Nabugabo was the most species rich site for amphibians with 25 species followed by L. Wamala (12) and Lake Victoria sites (11), while L. Mburo (7) and L. Kachera (8) were the poorest (Table 12).

Table 12: Amphibian fauna of the Lake Victoria basin, Uganda

(Source: Behangana and others 2004).

Species	Common name	L. Victoria	L. Mburo	L. Kachera	L. Wamala	L. Nabugabo	R. Nile
Afrana angolensis	Angola Frog	x			x	x	
Afrixalus fulvovittatus	Banded Banana Frog					x	
Amnirana albolabris	White-lipped Frog	x			x	x	
Amnirana galamensis	Marble-legged Frog					x	
Bufo gutturalis	Guttural Toad	x	x	x	x	x	x
Bufo steindachneri	Steindachner's Toad					x	
Bufo vitattus	Banded Toad	x			x	x	x
Hoplobatrachus occipitalis	Groove-crowned Bullfrog	x			x	x	x
Hyperolius acuticeps	Sharp-nosed Reed Frog			x	x	x	
Hyperolius cinnamomeoventris	Cinnamon-bellied Reed Frog	x				x	
Hyperolius kivuensis bituberculatus						x	
Hyperolius kivuensis kivuensis	Kivu Reed Frog	x	x	x	x		x
Hyperolius viridiflavus bayoni		x	x	x	x	x	x
Hyperolius viridiflavus variabilis	Variable Reed Frog					x	
Hyperolius viridiflavus viridiflavus	Common Reed Frog				x		x
Kassina senegalensis	Bubbling Kassina		x			x	
Leptopelis bocagii	Bocage's Tree Frog		x			x	
Phrynobatrachus acridoides	East African Puddle Frog					x	
Phrynobatrachus dendrobates	Medje River Frog					x	
Phrynobatrachus graueri	Rugege River Frog					x	
Phrynobatrachus natalensis	Natal River Frog			x	x	x	x
Ptychadena anchiatae	Benguella Grassland Frog					x	
Ptychadena chrysogaster	Yellow-bellied Ridged Frog					x	
Ptychadena mascareniensis	Mascarene Grassland Frog	x	x	x	x	x	x
Ptychadena oxyrhynchus	Kaffirland Grasslan	x		x		x	
Ptychadena porissisima	Ethiopia Grassland Frog	x	x	x	x	x	x
Xenopus laevis victorianus	African Clawed Frog					x	
Total		**11**	**7**	**8**	**12**	**25**	**9**

For reptiles, Lake Nabugabo had the highest richness with 15 species followed by Lake Victoria sites (12). Lake Wamala (4) and R. Nile (5) are ranked as the poorest (Table 13).

Table 13: Reptilian fauna of the Lake Victoria basin sites, Uganda (Source: Behangana and others 2004).

Species /Sites	Common Name	Lake Victoria	L. Mburo	L. Kachera	L. Wamala	L. Nabugabo	R. Nile
Adolphus jacksonii	Jackson's Forest Lizard		X				
Agama atricollis	Common Tree Agama		X	x	x	x	x
Atractaspis irregularis	Burrowing Viper	X				x	
Chamaeleo gracilis	Graceful Chameleon					x	
Chamaeleo laevigatus	Smooth Chameleon	X					
Cocodylus niloticus	Nile Crocodile	X	X	x			x
Crotaphopeltis degeni	Yellow-flanked Snake					x	
Dromophis sp.		X				x	
Mabuya maculilabris	Speckle-lipped Skink	X	X	x	x	x	X
Mabuya striata	Common Striped Skink		X	x		x	
Meheleya capensis	File Snake	X				x	
Naja melanoleuca	Water Cobra	X	X	x	x	x	X
Naja nigricollis	Spitting Cobra		X			x	
Natriciteres olivaceous	Olive Marsh Snake	X				x	
Pelomedusa subrufa		X				x	
Psammophis sibilans	Sand Snake	X				x	
Python sebae	Rock Python	X	X	x	x	x	
Varanus niloticus	Monitor Lizard	X	X	x		x	X
Total		**12**	**9**	**7**	**4**	**15**	**5**

As for mammals, Lake Nabugabo again has the richest diversity with 35 species followed by Lake Victoria (19), while L. Kachera (5), Lake Wamala (6) and the R. Nile (6) are the poorest (Table 14). Lake Mburo had 181 hippos making it the richest site for hippos in the Lake Victoria basin.

Table 14: Mammalian fauna of the Lake Victoria basin sites, Uganda (Source: Behangana and others 2004).

Species	Common Name	Lake Victoria	L. Mburo	L. Kachera	L. Wamala	L. Nabugabo	R. Nile
Aethomys kaiseri	Kaiser's Bush Rat					x	
Arvicanthis niloticus	Nile Grass Rat						x
Atilax paludinosus	Marsh Mongoose	X		x	x		
Cercopithecus aethiops	Vervet Monkey	X	X		x	x	
Cercopithecus ascanius	Red-tailed Monkey	X				x	
Chaerophon major	Lappet-eared Free-tailed Bat					x	
Chaerophon pumila	Little Free-tailed Bat					x	
Colobus guereza	Black and White Colobus Monkey	X				x	
Crocidura fuscomurina	Tiny Musk Shrew					x	
Crocidura infinetismus	Least Dwarf Shrew				x		
Crocidura littoralis	Butiaba Musk Shrew					x	
Crocidura luna	Greater Grey-brown Musk Shrew					x	
Crocidura mourisca	Northern Swamp Musk Shrew	x			x	x	
Crocidura olivieri	Northern Giant Musk Shrew	x	x			x	x
Crocidura turba	Southern Woodland Musk Shrew	x	x			x	

Dasymys incomtus	Shaggy Marsh Rat					x	
Epomophorus labiatus	Little Epauletted Fruit Bat					x	
Epomops franquenti	Franquet's Fruit Bat					x	
Geneta servelina	Serveline Genet	x	x			x	
Gramnomys dolichurus	Common Thicket Rat	x				x	
Hippopotamus amphibius	Hippopotamus	x	x	x			
Lemiscomys striatus	Common Striped Grass Rat						x
Lepus victoriae	Savanna Hare	x				x	
Lophuromys flavopunctatus	Eastern Brush-furred Rat					x	x
Lophuromys sikapusi	Common Brush-furred Bat	x		x		x	x
Lutra maculicollis	Spot-necked Otter	x	x	x	x	x	
Mastomys hildebrandtii	Multimammate Rat	x				x	x
Mus minutoides	Pygmy mouse					x	
Oenomys hypoxanthus	Rusty-nosed Rat	x				x	
Otomys tropicalis	Tropical Groove-toothed Rat					x	
Paraxerus alexandri	Alexander's Dwarf (Bush) Squirrel					x	
Pelomys hopkinsi	Papyrus Rat	x				x	
Praomys jacksoni	Jackson's Soft-furred Rat			x		x	
Rousettus aegyptiacus	Egyptian Fruit Bat					x	
Rousettus angolensis	Bocage's Fruit Bat					x	
Sylvicapra grimmia	Common (Bush) Duiker	x	x			x	
Sylvisorex megalura	Climbing Forest Squirrel					x	
Thryonomys gregorianus	Lesser Cane Rat					x	
Tragelaphus scriptus	Bushbuck	x				x	
Tragelaphus spekii	Sitatunga	x			x	x	
Total		**19**	**7**	**5**	**6**	**35**	**6**

Specific diversity on selected study sites of the Lake Victoria basin in Kenya

The Yala swamp complex consists of two rivers (Yala and Nzoia) and covers mainly the northern shores of Lake Victoria including the satellite lakes Sare, Kanyaboli, and Namboyo. Six amphibian species are reported in this swamp (Table 15). The African Clawed Frog (*Xenopus laevis*) is the most dominant species encountered in all satellite lakes.

Table 15: Amphibian fauna of the Lake Victoria basin, Kenya. (Source: Behangana and others 2004).

Species	Common Name	L. Sare	L. Kanyaboli	L. Nyamboyo	R. Yala	R. Nzoia	Yala swamp
Afrana angolensis	Angola Frog	x	X				x
Bufo maculates	Flat-backed Toad						x
Kassina senegalensis	Bubbling Kassina						x
Phrynobatrachus natalensis	Natal River Frog						x
Ptychadena chrysogaster	Yellow-bellied Ridged Frog				x	x	
Xenopus laevis	African Clawed Frog	x	X	x	x	x	
Total		**2**	**2**	**1**	**2**	**2**	**4**

Among the 13 species of reptiles recorded in the swamp, the commonest were *Grayia smithii* Leach 1818 and *Grayia tholloni* Mocquard 1897 (Table 16). The species richness adds up to 19 with opportunistic records outside the sampled sites but within the basin. The most specious sites are the macrophyte zones in the wetland with 7 species, while River Nzoia was poorest (3 species).

Table 16: Reptilian fauna of the Lake Victoria basin, Kenya. (Source: Behangana and others 2004).

Species	L. Sare	L. Kanyaboli	L. Namboyo	R. Yala	R. Nzoia	Yala swamp (macrophyte zone)
Adolfus jacksoni						
Cansus lichtensteinii				X		
Crocodilus niloticus						
Crotopholpeltis degeni	x	x	x			
Grayia smythii	x	x	x	X	X	
Grayia tholloni	x	x	x	X	X	
Hemidactylus mabouia						
Latastia longicaudata						
Leptotyphlops conjuctus						X
Lygodactylus marini						
Naja melanoleuca				X	X	
Naja nigricollis						X
Philothamnus carinatus						X
Philothamnus heterolepridotus				X		X
Philothamnus niticlus	x	x	x			X
Philothamnus semivariegatus	x	x	x			
Psammophis mossambicus						X
Python sebae				X		X
Varanus niloticus						
Total	**5**	**5**	**5**	**6**	**3**	**7**

Eight species of mammals were recorded from the Yala swamp (Table 17), the Hippopotamus (*Hippopotamus amphibius*) being the commonest. The list excludes small mammals, which are generally very difficult to locate.

Table 17: Mammalian fauna of the Lake Victoria basin, Kenya. (Source: Behangana and others 2004).

Species	Common name	L. Namboyo	L. Kanyaboli	L. Sare	R. Yala	R. Nzoia	Yala swamp
Cercopithecus aethiops	Vervet Monkey						x
Epomophorus wahlbergi	Wahlberg's Epauletted Fruit Bat						x
Hippopotamus amphibius	Hippopotamus	X		x			x
Kobus ellipsiprymnus	Defassa Waterbuck						x
Phacochoerus aethiopicus	Common Warthog						x
Redunca redunca	Bohor Reedbuck						x
Tragelephus scriptus	Bushbuck						x
Tragelophis spekii	Sitatunga						x
Total		**1**	**0**	**1**	**0**	**0**	**8**

Specific diversity on selected study sites of the Lake Victoria basin in Tanzania

Published information on species diversity of amphibians that occur in the Lake Victoria basin - Tanzanian side is very scanty. Frogs and toads are, however, believed to utilise a wide range of habitats, including palustrine swamps, marshes, ponds, streams, irrigated paddy fields, inundated floodplains, and reservoirs. Of the 10 species recorded in the lake basin, *Ptychadena* spp were the most widely spread in vegetated streams, springs, and rice fields.

Table 18: Amphibian fauna of the Lake Victoria basin, Tanzania.

(Source: Behangana and others 2004)

Species	Common name
Afrixalus brachycnemis	Short-legged Spiny Reed Frog
Afrixalus fulvovitattus	Banded Banana Frog
Amnirana galamensis	Marble-legged Frog
Bufo kerinyagae	Kenya Highlands Toad
Hoplobatrachus occipitalis	Groove-crowned Bullfrog
Hyperolius viridiflavus	Painted Reed Frog
Kassina senegalensis	Bubbling Kassina
Ptychadena mascareniensis	Mascarene Grass Frog
Xenopus laevis	African Clawed Frog
Xenopus muelleri	Muller's Clawed Frog

Studies conducted around Lake Victoria on the Tanzanian side showed that inshore waters and the fringing wetlands support many species of reptiles, including the Nile Crocodile (*Crocodylus niloticus*), Monitor Lizards (*Varanus niloticus*) and snakes such as the African Rock Python (*Python sebae*) (Chisara and others 2001). No specific accounts exist on reptiles and mammals, but based on information drawn from local knowledge, citations from Rubana and Simuyu ecosystems given vernacular names are listed below with assigned scientific names (Table 19 and 20).

Table 19: Common reptilian fauna of the Lake Victoria basin, Tanzania. (Source: Behangana and others 2004).

Local name	Swahili name	Scientific Name	Common Name	Rubana	Simiyu
	Mamba	*Crocodylus niloticus*	Crocodile	X	x
Mbulu-kenge,	Kenge	*Varanus niloticus*	Monitor lizard	X	x
	kasa,	*Pelomedusa subrufa*	Tortoise	X	
	Kobe				x
Chatu, satu, ebhasoti		Naja melanoleuca	Water Cobra		x
Ibambahili					x
Ibiheke				X	
Indugi				X	
Kifutu				X	x
Kinyarunyasi				X	
Kiwira				X	
Koboko				X	x
Mbubi, njubi, mbubi wa majini				X	x
Ndelema		*Python sebae*	Python	X	x
Nghimbeji					x
Ngoboko					x
Nyakehacha				X	
Nzoka ya rudutu				X	x
Nzubi					x

Local name	Swahili name	Scientific Name	Common Name	Rubana	Simiyu
Sawadi					x
Shana				X	x
Shilwe					x
Swila				X	x
Swila wa majini					x
Wange					x
Chura,			Frogs	X	
Total				**16**	**19**

Table 20: Common mammals recorded at Rubana and Simiyu wetlands, Tanzania. (Source: Behangana and others 2004)

Scientific name	Common Name	Rubana	Simiyu
Hippopotamus amphibius	Hippopotamus	X	X
Lutra maculicolis	Spot Necked Otter	X	X
	Wildebeest	X	
Cercopithecus aethiops	Velvet monkey	X	X
Potamoceros porcus	Bushpig	X	X
Tragelpus spekii	Sitatunga	X	X
Crocutta crocuttq	Spotted hyaena	X	X
Felis pardus	Leopard	X	
Thyronomys gregorianus	Cane Rat		X
Madoqua guentheri	Dik dik		X
Histrix cristata	Crested Porcupine		X
Lepus victoriae	Savvana Hare		X
Papio anubis	Olive Baboon	X	X
Total		**9**	**11**

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Energy and Environment in the Lake Victoria basin

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ABSTRACT

The local and national economies of Lake Victoria basin communities are heavily dependent on energy that fuels agriculture, industry, commerce, transportation and other economic activities; and powers our houses, offices, hospitals and buildings. Energy is therefore key to facilitating the development income generating opportunities, improving living standards, reducing poverty, and ensuring the protection of the environment. The development and use of various forms of renewable and non-renewable energy sources in the basin have been discussed. The link between the energy sector and the environment has also been presented through the impact of energy development and use on environmental and human vulnerability. The impacts, as presented in the review, if not controlled, may lead to climate change – locally and regionally with attendant reduction in energy potential in the basin, and reduced general economic activity. A number of actions for improving access and availability of energy in the Lake Victoria basin are suggested and discussed including increased support for sustainable production and efficient utilization of biomass; more widespread development and use of renewable energy sources and technologies; improved information energy resource base and demand; enhanced energy efficiency and conservation; creation of an enabling environment; gender sensitivity; promotion of research and development in energy; provision of adequate energy services to rural areas; establishment of suitable legal, regulatory and institutional framework; international and regional co-operation; and the development of adequate national and transboundary energy policy.

Key words: *Lake Victoria basin, renewable energy, non-renewable energy, energy generation, co-generation, energy potential*

ENERGY AND SUSTAINABLE DEVELOPMENT

Energy and Socio-economic Development

Energy plays a critical role in achieving interrelated economic, social and environmental objectives of sustainable development[15]. It facilitates all human endeavours and is essential to life. It fuels agriculture, industry, commerce, transportation and other economic activities; and powers our houses, offices, hospitals and buildings. At the individual level energy satisfies basic human needs for food (cooking, lighting and heating), jobs, clean running water, health services, housing, education, and communication, among others. By so doing it plays a decisive role in poverty reduction.

Modern economies are heavily dependent on energy; further growth in these economies will, therefore, result in increased needs for energy services. In developing countries, particularly those in Africa, emphasis will be on:

a. Facilitating the development income generating opportunities;
b. Improving living standards - improve health, educational services;
c. Reducing poverty;
d. Ensuring the protection of the environment.

15 United Nations, Committee on New and Renewable Sources of Energy, Report of the second session (12-23 February 1996); Economic and Social Council Official Records, 1996 Supplement No.4

Towards better energy development and use

The international community has in recent times extensively deliberated on the issues and problems relating to energy and sustainable development and has come to a consensus that the current patterns of production, conversion, distribution and use of energy are wasteful, environmentally unsound and unsustainable. It has, therefore, underscored the need to better develop and use energy resources and has called for a strategy to this end. Such a strategy should entail (a) a more efficient production, conversion, distribution and use of energy; (b) increased development and use of environmentally sound renewable energy technologies; and (c) a shift towards environmentally sound, safe, efficient and cost-effective fossil fuel as well as other technologies. To this end the international community, Governments, the private sector and non-governmental organisations should pursue the development, promotion and implementation of policies and programmes, as appropriate, designed to realize the goals of such a strategy[16]. These should be the guiding principles by all countries when addressing questions on energy and sustainable development.

In the move towards a better development and use of energy, certain issues emerge that need emphasis; a number of these are touched upon below. Adequate availability of energy and access to energy services are a prerequisite to sustainable development. An important requirement to this end is that energy supplies should be adequate and reliable. Moreover, the development of energy should be consistent with the pursuit of sustainability i.e.:

a. It should not endanger the quality of life of present and future generations;
b. It should not exceed the carrying capacity of existing ecosystems;
c. The use of scarce resources to fulfil the present needs of energy services should not compromise the ability of future generations to meet their needs for the same services.

All this requires an efficient production, conversion and use of energy resources and timely development of alternative sources; and, in the process, reduction of wastes.
Another key stipulation is that the development of short-term goals should not hinder the development of options that in the longer run contribute to sustainable development.

The development and use of energy resources should be consistent and linked with the national socio-economic development strategies, and should, moreover, address the issues of equity in the context of affordability by the poor and gender questions pertaining to empowerment of women.

ENERGY DEVELOPMENT AND USE

This section gives a brief coverage of energy resources and use in the Lake Victoria basin – including biomass, petroleum and renewable sources of energy.

Biomass

For the purposes of the present discussion, biomass energy is classified into two categories: (1) traditional biomass energy, that is, firewood, charcoal and agricultural residue; and (2) modern biomass energy, including bio-fuels (ethanol and bio-diesel), biogas, and briquettes.

Traditional biomass

Traditional biomass energy is a major source of livelihood for the population in rural and urban areas in the Lake Victoria basin. Woody biomass is the preferred source, with others such as agricultural residue consumed only when woody biomass is in short supply. Increasingly, woody biomass is being converted to charcoal, a more convenient form, for transportation and use, mainly in urban areas. The energy conversion, carried out mainly using traditional earth kilns, is very inefficient. Meanwhile, the

16 Ibid Op Cit 1

use of woody biomass, mainly for cooking involves stoves with very low efficiencies. Wood harvesting still remains inefficient, with significant energy losses. All this has led to wastage of raw material, and contributed to environmental degradation including loss of biodiversity and soil erosion.

Fuel wood is widely used by many households in the Lake Victoria basin with rural households commanding the largest share. Cow dung and crop residue are also widely used in the rural areas as domestic fuel while some factories use wood waste such as timber off-cuts, rejects and wood shavings, for steam generation.

The cottage industry sub-sector is a major consumer of biomass energy. Micro enterprises in the rural areas use biomass energy for brick making, tobacco curing, milk processing, fishing and fish smoking, bakeries restaurants and kiosks, to name a few.

Modern biomass

Biomass energy can be converted into more convenient forms such as gases or liquids including power alcohol, cogeneration, municipal waste and biogas.

Power Alcohol

Power alcohol was marketed in Kenya as a fuel blend with gasoline, known as gasohol, between 1983 and 1993 but was discontinued thereafter because of management and pricing problems. Since 1993, the plant in Muhoroni has been producing potable and industrial alcohol for both domestic and export markets. A major reason for the discontinuation of power alcohol as a motor fuel in Kenya was its relatively higher cost of production compared to petrol, which it was meant to displace. Kenya and other riparian countries can learn from experiences in other African countries, such as Zimbabwe, that have successfully implemented ethanol programmes. The challenge is to make the domestic production of power alcohol competitive with gasoline in order to facilitate its re-introduction as a motor fuel blend.

Co-Generation (Combined Heat and Electricity Generation)

Kenya is among the riparian countries with some experience in co-generation using bagasse (a waste product from sugar processing) as a primary fuel. Western Kenya is home to the bulk of the domestic sugar industry from which bagasse is derived. All the seven sugar companies in the Western Kenya region have been involved in one way or another in co-generation. However, because of a host of management, financial and other problems, only Mumias Sugar Company is self-sufficient in electricity from the use of bagasse and has a limited capacity for export to the national grid. Nevertheless, opportunities exist for increased co-generation, not only in Kenya, but also in other riparian countries, particularly Uganda where sugarcane production is also high.

Municipal Waste Energy

Municipal waste energy projects are instituted as waste management options with energy as a by-product. Major urban centres in the basin continue to experience serious refuse collection problems because of, among others, serious governance deficiencies. Most of the refuse ends in Lake Victoria and constitute a leading environmental problem. With appropriate management of municipal waste, it is possible to generate revenue to cover operating costs for the collection of refuse and treatment of raw sewage through electricity generation and sale, and in the process address environmental concerns associated with the disposal of the municipal waste.

Biogas

Biogas is a clean-burning, methane-rich, gas produced through anaerobic digestion (bacterial action in the absence of air) of organic feedstock (crop residues, animal dung, food waste, etc.). Although biogas is a viable substitute for wood-fuel, kerosene and liquefied petroleum gas (LPG) for cooking and lighting, its use is not widespread in the lake basin region.

Among the contributing factors are (a) high capital costs for not only the plant, but also the modified burners and lighting units; (b) inadequate maintenance and management and technical support services - the plants are prone to cracking and leaking yet their operations require that they be air and water-tight; (c) lack of adequate supplies of water; and (d) poor system design.

Petroleum

All the requirements for petroleum in the riparian countries and in the Lake Victoria basin are imported. This constitutes a huge import bill with attendant negative balance of payments for each of the countries. The transport sector accounts for the largest share of petroleum consumption. The industrial sector is also a major consumer of petroleum in the form of products. Moreover, petroleum fuels are used in the thermal generating plants and to fire small-scale stand alone diesel generators. In addition, the residential sector consumes significant quantities of petroleum products in the form of kerosene and LPG.

Renewable sources of energy

The Lake Victoria basin is well endowed with significant amounts of renewable energy sources, including biomass (discussed above), hydropower, solar and wind. The contribution of renewable energy sources to total energy supply is currently very low: estimated at less than one per cent. These energy sources, however, have the potential to significantly improve access to improved energy services for majority of the population.

Renewable energy sources can, in the long term, be harnessed to meet a significant portion of the country's energy needs without impairing the ecosystem. Furthermore, with prudent management, these resources would contribute to the security of energy supply at increasingly competitive prices and to national development. Specific sources such as solar, hydropower and wind are discussed below.

Solar Energy

Lake Victoria basin receives solar insolation all year round coupled with moderate to high temperatures. Solar energy has become competitive under varying conditions for water heating and crop drying. In most of these areas, it is viable for refrigeration and as a substitute for diesel powered water pumping. The use of solar thermal energy is not widespread in the basin. More widespread use of solar water heaters would make a significant impact on electricity use for water heating, especially in urban areas where such heating is mostly by electricity.

Solar driers have a huge potential in the agricultural sector in food preservation. In many developing countries, the use of solar drying devices is becoming an important part of agriculture or business, especially where the product can be sold at a higher price or transported more easily when dried. This is aimed at adding value to the products. The potential for solar drying in the lake basin region is huge. Product candidates for solar drying are cereals, fish, vegetables, coffee fruits, vegetables, tea, lumber, maize, fish, meat hides and skins. The benefits of solar drying in terms of equivalent energy savings are enormous. Nevertheless, the use of this technology in the region has not yet become widespread.

There is also a high promise for the development and more widespread use of photovoltaic (PV) systems for lighting, telecommunications, water pumping, battery charging and refrigeration. While the overall number is relatively small, more and more photovoltaic systems have been installed in the region in the last several years, a clear indication that PV technology is gradually becoming popular especially by those outside the national grid – for a variety of applications such as lighting, telecommunications and battery charging.

In Kenya, although the government has subsidised the technology, by zero-rating import duties of PV equipment, there is no evidence that the poor, especially those in the lake region have benefited from the intervention. Solar photovoltaic systems are expensive with limited productive and income generating end uses.

Hydro-electric resources

The main rivers flowing into Lake Victoria are the Kagera, Mara, Simiyu, Gurumeti, Nyando, Migori and Sondu rivers. There is a huge hydroelectric resource potential in the Lake Victoria basin including Sondu-Miriu hydroelectric power project now under development. Nevertheless, detailed resource assessments have only been done for a small number of sites in the whole region; there is, therefore, need to carry out comprehensive assessment of these resources.

In addition, there is a large potential in the category of small-scale hydropower sites currently considered to be uneconomic to exploit. A small-scale hydropower site is classified as that whose potential does not exceed 10MW of installed capacity. Pre-feasibility studies of these sites may, however, establish their economic viability compared to isolated diesel fired plants. Here too there is a need for carrying out detailed studies of such sites to ascertain their economic competitiveness when compared to grid extension or to isolated diesel fired plants. Small-scale hydraulic energy is not confined to electricity generation only. There are, in addition, numerous mechanical applications such as grain milling, water pumping and agro-processing (including extraction of oil from seeds).

A variety of factors have constrained the exploitation of small-scale hydro resource. High costs, lack of awareness on the part of users and destruction of catchments areas are among the key factors contributing to the low level of exploitation. Shortage of data on hydrology and on comparative economics of these power sources as well as lack of infrastructure for local manufacture is a major drawback to the exploitation of the small hydro resources.

Wind

Wind is an important resource in the Lake Victoria basin, with vast potential for water pumping, grain milling and in future power generation. The resource is, however, relatively under-utilised and has, for most part, been used mainly for water pumping and to some extent grain milling. A major limitation in the development of wind energy in the region is the lack of adequate wind resource data and information to assist investors in decision-making.

In summary, renewable energy sources have the potential to meet energy demand for various sectors of the economy and to substantially meet national social objectives. The potential of renewable energy sources is, however, limited by a number of factors, the most common of which are high costs and limited priority afforded them by policy- and decision- makers and planners. In order for these energy sources to play a significant role in meeting the energy demand in the various sectors of the economy, the following challenges will need to be overcome: (i) high capital costs of most renewable energy sources; (ii) low priority given to renewable energy development in national development and planning; (iii) lack of appropriate credit and financing mechanisms for renewable energy development and technologies; (iv) lack of institutional, legal and regulatory frameworks or development of renewable sources of energy; (v) lack of awareness and information on energy opportunities and economic benefits offered by renewable sources of energy; (vii) inadequate data on renewable sources of energy resource potential; (viii) high cost of undertaking feasibility studies and associated viability risks (small hydro, wind, solar thermal); (ix) limited local capability to manufacture and maintain renewable energy systems, (xi) inappropriate system standards, faulty installations and importation of poor and sub-standard systems which have led to erosion of consumer confidence; (xii) market barriers; (xiii) lack of adequate information on potential environmental impacts arising from production and use of energy; and (xiv) inadequate priority to research and development on renewable energy sources.

LINK BETWEEN ENERGY SECTOR AND THE ENVIRONMENT

All economies worldwide are critically dependent upon energy. Economic activities involve the use of matter and energy, which eventually return to the natural environment in the form of wastes. The amount and structure of energy use are, therefore, fundamental to environmental concerns and environmental

policy.[17] Interconnection between energy and the environment poses major issues concerning the treatment of the future with regard to current environmental stewardship that does not jeopardize the future state of the environment.

Environmental impact of energy development and use

The development and use energy have a direct impact on the quality of environment. For example, the production conversion, transport, distribution and use of fossil fuels have varying degrees of environmental consequences such as air, land and water pollution and emissions of Greenhouse Gases (GHGs), with attendant emissions and impact on climate at local and global levels. The impacts are to be found throughout the entire chain of activities and manifest themselves in short, medium and long time ranges; they also have cascading effects by combining with other environmental problems.

Biomass energy combustion results in air pollution including indoor air pollution with attendant health implications, particularly respiratory tract infections. There is, therefore, need to shift to improved biomass energy resources, e.g. biogas, that do not emit significant greenhouse gases and do not contribute to indoor air pollution; efforts should thus be intensified in modernizing the sector.

Unsustainable production and un-regulated charcoal burning have negative impacts on tree depletion, soil erosion, and land degradation and food security. To stem these trends, support should be given to sustainable biomass production and utilization. The use of leaded and high sulphur fuels significantly contributes to high air pollution; so does the lack of adequate standards, codes and regulations. Kerosene use also has environmental impacts that in turn depend on the degree use and the type of technology applied. Meanwhile, as indicated in section 3.4, judicious use of energy can play an important role in economic and social development.

Other activities that adversely impact on energy production and supply

The population in the Lake Victoria basin has been growing steadily over the years. At the same time the population has been associated with a number activities, mainly for sustenance, but broadly definable as 'developmental', such as the expansion of agricultural land necessitating land clearance and deforestation. Bad agricultural practices have also resulted in massive soil erosion[18].

There has, over the years, been intense cultivation of marginal areas and clearance of natural habitats like wetlands, forests and mountainous areas. The incremental loss of natural habitats has reduced vegetation cover exposing soils to both wind and water erosion, further worsening the degradation problem[19]. Over and above these are activities related to harvesting of forests and other vegetation for timber (for a variety of applications) and for fuel-wood. These activities have also damaged catchment areas, giving rise to the silting of rivers from soil erosion: this may in turn affect hydropower development in such rivers through:

- Damage to turbines and therefore shortening of economic life; this is reflected in additional costs for operating the plant;
- Dams filling up faster, reducing dam's carrying capacity and, therefore, level of electricity generation; this results in added cost to dredge the silt from the dam;
- Decreased channel capacity resulting from sedimentation.

17 Editors' Introduction; Special Issue on Energy and Environment, David Pearce, Ed.; Energy Policy, Vol 17 Number 2 April 1989

18 Wandiga, Shem, O; Lake Victoria: will it support life tomorrow? A case for abatement of pollution and eutrophication of fresh waters, 2-4 September 2004

19 Washington *Odongo Ochola,* Land cover, land use and related issues in the Lake Victoria Basin, 2-4 September 2004

These events would lead to a reduction in electricity generation; at same time reduced electricity production may be reflected in interruption of supplies. Either case would result in reduction in economic activities, nationally and at the local level.

Alternatively, reduced hydroelectric generating capacity from the above effects would lead to increased use of fossil fuels for electricity generation. The overall impact may be:

- Increased operating costs if the fossil fuel plants cost more;
- For the riparian countries this would be reflected in increased bills from the importation of petroleum products and attendant poor balance of trade;
- Increased pollution, including the emission of GHGs.

The continuing loss of vegetation cover as well as general deforestation and attendant soil erosion and land degradation all have aggravated fuel-wood shortage and scarcity. As a result more time is spent in looking for and fetching wood; literally scrapping the land for whatever little wood fuel left - resulting in further degradation of land. When wood fuel is not readily available the population is left with little choice but to scramble for agricultural waste, further robbing the land of much needed nutrients, leading to even worse degradation of the land and hence reduced agricultural productivity.

The above-mentioned human activities in the Lake Victoria basin may, if not controlled, also lead to climate change – locally and regionally with attendant reduction in hydroelectric potential in the rivers, and in some cases in the reduced general economic activity.

Contribution to socio-economic development

As noted, energy is at the core of socio-economic development and environmental protection. Petroleum is crucial to transportation, industry and, agriculture, commerce and in satisfying basic human needs - in the provision of food (cooking and lighting), clean water, health, housing, communications, and others. It, therefore, contributes to poverty reduction. Transportation is by far the largest user of petroleum in the region; and transportation is vital for the economic and social development of the region.

Enhanced availability, access to and usage of petroleum products in the basin should result in increased productivity in such areas as manufacturing and hence lead to improved economic development. Accessibility of modern forms of energy in the form of fuel for cooking positively impacts the basin's population through better health, not to mention improved utilisation of time.

There is scope for increasing electricity supplies in the Lake Victoria basin through, among others, harnessing hydroelectric resources from the rivers in the basin for electricity supplies. Electricity is the most versatile form of energy with high capacity for social transformation and contribution to national development; indeed there is a strong correlation between the par capita use of electricity and standard of living. Electricity is primarily used as a prime mover of economic growth in the industrial, commercial and service sectors and informal sectors and provides jobs to thousands in the region directly or indirectly. Electricity also plays a crucial role in, for example, fish preservation (cooling), and processing, and for ice making.

Furthermore, electricity has the potential of increased contribution to food security through irrigation as well as food processing and preservation. The sub-sector is well placed to play an even greater role in the creation of employment, infrastructure and service delivery, better productivity, and environmental protection. But access to electricity in the rural areas in the region is meagre; nevertheless, it is used to promote social economic development in these areas through the provision of services to basic social activities including health, education, water, sanitation and information. The hydraulic resources would also be important for irrigation and flood control, as part of the multipurpose development of suitable locations in the rivers in the basin.

Because of inadequate data and information, the exact contribution to socio-economic development by renewable energy sources is not well understood. Yet the contribution can be significant. Local

manufacture of renewable energy technologies may create jobs and enterprises, and thus lead to the generation of incomes and to general economic development. Moreover, renewable energy resources that replace petroleum could significantly reduce import expenditures and thus improve the country's balance of payments situation.

Biomass energy provides energy for local enterprises, and thus creates employment. Agro-forestry practices and woodlots also provide a wide range of benefits to the rural poor; for example, rural women who practice agro-forestry spend less time gathering wood. Biomass energy supplies stabilise local price levels and thereby play an important role in controlling inflation. In rural and peri-urban areas, biomass energy provides most of the fuel for small-scale industries (bakeries, brick-making, fish-smoking etc) and service establishments. The small-scale industries employ over a large number of people. The production and sale of charcoal alone significantly contributed to employment, income generation and trade, accounting for billions of Kenya shillings in the basin.

RESPONSES TO AND ALTERNATIVE OPTIONS FOR ACTION

A number of actions for improving access and availability of energy to the Lake Victoria basin are suggested and discussed below. These include increased support for sustainable production and efficient utilization of biomass; more widespread development and use of renewable energy sources and technologies; improved information energy resource base and demand; enhanced energy efficiency and conservation; creation of an enabling environment; gender sensitivity; promotion of research and development in energy; provision of adequate energy services to rural areas; establishment of suitable legal, regulatory and institutional framework; international and regional co-operation; and the development of adequate national energy policy. The actions have not been listed in any order of priority; neither is the list exhaustive.

Support for sustainable production and efficient utilization of biomass

Biomass continues to be the largest source of energy in the basin. It is, therefore, essential to significantly increase support for sustainable production and efficient utilization of biomass energy. This may involve such actions as (a) coordinating decision-making involving vegetation management; (b) promoting fast maturing energy crops; (c) encouraging commercialisation of fuel-wood plantations; (d) carrying out biomass resource assessment; and (e) promoting modern biomass practices such as agro-forestry, the integration of tree crops in farming systems, woodlots establishment on rural people's land and other woodland resources.

Increased development and use of renewable sources of energy

There is a compelling need to put in place measures for increased development and wider use of renewable energy sources in view of their considerable potential for providing environmentally sound energy to the domestic economy; and for ensuring diversity of supply options as well as increasing access to energy services to majority of the population in the lake basin region. There is also a need to promote the use of renewable energy in rural areas for basic and productive purposes

The desirable actions are to accelerate the exploitation of solar, wind, hydro and modern biomass to thereby increase energy availability and supply and substitute other forms of energy, particularly fossil fuels as well as traditional biomass; this would maximise the economic and social well-being of the region, and to help re-dress the massive trade imbalance in the riparian countries arising from continued importation of petroleum and products.

Improved information energy resource base and demand

Data and information - on past and current energy needs, on resources and supply options, on future requirements and future supply possibilities - are of crucial importance in understanding the prevailing energy situation and in formulating an energy policy. The value and reliability of information are also

key issues in this exercise. Moreover, the quality and usefulness of information are enhanced through painstaking processing and analysis of data.

Of equal importance is the way the information is presented. Programmes should, therefore, be developed and put in place for accurate inventory of energy resources and for accurate data on energy use as well as on production and conversion processes. Similarly, improved techniques should be developed and deployed to accurately assess the socio-economic and environmental impacts of different energy options. Suffice it to say, obtaining accurate data is a daunting task requiring the involvement of expert personnel, hence the compelling need for capacity building in this area. The task of forecasting future energy demand, availability and supplies is even more overwhelming; for such an exercise involves careful appraisal of future price expectations and on the trends of international and regional resource availability as well as judgement on such matters as anticipated economic and industrial growth, changes in economic structure, government policies on a variety of issues - such as efficiency in energy production, conversion, distribution and use, and on environmental standards.

Currently, there is inadequate data on the energy resource base in the Lake Victoria basin in particular in regard to biomass, and whether or not the rate of use of the biomass resource is outstripping that for its replenishment. The same is true of other energy sources such as renewable ones and their technologies. Data available on traditional biomass, for example, does not make a clear distinction between consumption and demand; meanwhile data on the demand for renewable energy sources is not readily available. These are among the problems that need to be addressed as a matter of urgency.

Enhanced energy efficiency and conservation

Energy conservation and efficiency in production, conversion and use are crucial for socio-economic development and protection of the environment. There are persuasive reasons for improving energy conservation and efficiency in the basin. They are key instruments in socio-economic development and environmental protection through reduced emissions. They reduce energy consumption per unit of Gross Domestic Product (GDP). Moreover, they lead to new capacity investment. At the business level, this would reduce costs and boost productivity, thus enhancing a company's ability to compete. At the national level this would improve international competitiveness, reduce foreign exchange expenditures, create jobs, reduce poverty and better protect the environment.

There are, however, barriers to energy conservation and efficiency. These include (i) low awareness on economic viability of energy conservation and efficiency measures; (ii) inexperience and lack of technical capacity in identifying energy efficiency options, (iii) inability to secure financing for energy efficiency and conservation projects; (iv) lack of institutional mechanisms to mainstream efficiency and conservation; (v) Absence of standards, regulations and codes; (vi) low participation by the private sector; and (vii) uneven market/trade practices.

On-going energy efficiency programmes include demand side management in the electricity sub-sector and (in Kenya) the industrial efficiency and conservation project. At household level, efficient cook-stoves were introduced and are now fully commercialised. However, the investment in energy efficiency and conservation has remained low; as a result the necessary measures have not been widely adopted. There is need to promote private sector involvement in energy efficiency and conservation, utilise fiscal incentives, improve awareness on the potential and practice of energy conservation and efficiency improvements and also encourage energy efficiency and demand side management by the electric utility companies.

Creation of an enabling environment

The provision of adequate energy services to Lake Victoria basin can best be achieved by the riparian countries through the creation of an enabling environment that encourages broad participation of stakeholders, including public- private sector partnerships, non-governmental organisations (NGOs)

and the donor community. This requires political stability and reliability; and transparency in governance as well as transactions, both in the public and private sectors.

Stakeholders can play a crucial role in the development of suitable policies for a sustainable energy future by:

a) Bringing to bear their experience and expertise as developers and users of energy and related services;
b) Providing information and generating heightened public awareness of sustainable energy resources;
c) Mobilizing financing for sustainable energy resources and technologies;
d) Development, acquisition, adaptation and use of environmentally sound energy technologies;
e) Being receptive to new energy technologies and willingness to pay the full costs of such technologies.

Gender sensitivity

More than half of the population in Lake Victoria basin are women, who are affected, in one way or another, by the production, conversion, distribution, supply and use of energy. The level of impact is higher in the rural areas. Traditional household chores such as energy production, preparation and use are primarily the role of women, who in the process spend an inordinate amount of time on the supply of energy, a role that has not been adequately recognised. Rather it is the men, who engage in commercial energy production for profit mostly at subsistence level, that have received recognition as participants in energy activities. This has hindered women's efforts to improve their living conditions and move out of poverty.

Energy scarcity and general poverty tend to be a burden to women, who are, by and large, more vulnerable than men. Moreover, because women are marginalized, they have fewer options and opportunities than men. Furthermore, the lack of energy services limits women's productive and community development activities - entrepreneurial opportunities and opportunities for poverty reduction. It is, therefore, of crucial importance to ensure that energy activities, projects, policies and policy implementation are gender sensitive. Greater sensitivity to gender disparities especially to women's concerns can improve delivery of energy given the role of women in energy management at the local level.

Promotion of research and development in energy

Research and development (R&D) plays a critical role the development, conversion, transport and use of energy. Research and development in energy in the riparian countries is minimal or non-existent. None of the countries has established central data and information systems for energy, a pre-requisite for undertaking effective research and development; neither do they have adequate capacity to process data and information on energy development and use.

There is thus a need to strengthen this role by building or strengthening national institutions and institutional capacity; encouraging partnerships between public, academia, civil society, and the private sector in problem definition and research; facilitating regular consultations between researchers and policymakers; encouraging the establishment and nurturing of strategic linkages with regional and international knowledge networks; facilitating access to appropriate information systems; facilitating information and data collection, and analysis; and ensuring widespread dissemination and use of R&D outcomes in the sector's development. To this end it would be necessary to mobilize adequate resources and to allocate them expeditiously.

Provision of adequate energy services to rural areas

It is essential to improve access to energy services in the rural areas in the basin. Access and adequate availability of energy services is a pre-requisite to achieving desired socio-economic development goals, including poverty reduction and environmental protection. The supply of energy should be secure and reliable; moreover, access to energy services should be realised at affordable costs. The development of energy resources creates opportunities for employment and new industrial activity in the rural areas.

The provision of adequate energy services to rural areas where the bulk of the population live is crucial. Moreover, rural populations depend mainly on traditional forms of energy (mainly wood fuel) whose rate of consumption is out-stripping the rate of supply. It is also in the rural areas where poverty is also rampant and where important access to modern energy services would go a long way toward alleviating poverty.

Establishment of suitable legal, regulatory and institutional framework

Legal, regulatory and institutional frameworks are crucial for effective implementation of an energy policy. Legislation provides a basis on how to regulate, manage and develop the energy sector by creating an administrative framework and procedures for managing the sector - covering exploration, production, conversion, transmission, distribution, marketing and use. The legal environment that establishes and controls the operation of a regulatory regime is very important in determining the effectiveness and efficiency of the regulatory process. The establishment of a suitable regulatory framework is a vital component in the formulation and implementation of an energy policy.

There is also a need to establish appropriate laws, regulations and institutions, in the respective riparian countries, to assist in streamlining the energy sector to promote the adoption of conservation practices including end use practices, mobilize funds for efficient and sustainable production and utilization and to support dissemination of improved biomass cooking and heating technologies; generate awareness on efficiency and conservation potential; and promote efficient delivery, distribution and storage of charcoal.

Of equal importance is the promotion of capacity building, including the strengthening or establishment of institutions. This is essential for efficient guidance of the energy sector, the promotion of public services, the promotion of indigenous talent, and for the promotion of new investments in the sector. Human, technical and financial resources are still inadequate in the riparian countries, much more so in the basin, thus imposing severe restraints on their domestic capacity to meet the requirements of developing and using suitable energy systems. There is a need to strengthen capacity, including related institutions.

International and regional co-operation

There is a compelling need to intensify international co-operation including South-South co-operation in order to help develop environmentally sound, cost effective and affordable energy systems. Such co-operation is also essential for promoting energy efficiency improvement and conservation, the use of renewable energy sources and technologies, research and development, dissemination of information on innovative technologies. International co-operation is also required for assisting national efforts by developing countries in capacity building; in this regard, special attention should be given to strengthening the ability of developing countries to absorb, adapt and generate sustainable energy technologies.

Of particular import is the strengthening of regional co-operation. This would usher in efforts aimed at regional development of large resources – large scale hydro, gas, coal - to supply energy requirements in the sub-region or region, electricity interconnections, regional or sub-regional power pools and gas or oil pipelines. Co-operation would also play a key role in helping develop research and development capacity of the riparian countries.

Development of adequate national energy policy

Given the critical role that energy plays in socio-economic development and in the protection of the environment, there is a compelling the need by each of the riparian country to develop an integrated, comprehensive national energy policy, consistent with the overall national development objectives.

Such a policy should, among others, ensure access and availability of energy to all parts of the country and all sectors of the economy; promote energy efficiency and conservation; provide an enabling environment for the achievement of sustainable supply and use of energy resources; enhance security and reliability of supply; promote development of indigenous energy resources; significantly increase

support for sustainable production and efficient utilization of biomass; put in place measures for increased development and wider use of renewable energy sources; strengthen local and national capacity for analysis, planning, implementation and management in the energy sector, and for manufacturing and maintenance of energy technologies; enhance research and development including information collection, analysis, and dissemination; facilitate an inclusive, participatory process to energy planning and issues to ensure that the needs of both the people and all sectors of the economy are addressed; promote and develop appropriate partnerships between civil society, private sector and public sector; ensure integration and harmonization of policies, plans, strategies and operations of the energy sector and sub-sectors, and with policies of other sectors of the economy; and strengthen regional and international cooperation, including south-south cooperation in the field of energy.

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Natural disasters in Lake Victoria Basin (Kenya): Causes and impacts on environment and livelihoods

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ABSTRACT

The paper puts into context, the main forms of natural disastors that predisposes the environment and inhabitants of the Lake Victoria basin to vulnerabilities. Singling out drought and floods as the most devastating natyral harzards, the paper presents a conceivable drivers of the the two phenomena, their social, economic and environmental consequences as well as opportunities for prevention, mitigation and management The social and biophysical characteristics that increase vulnerabilities to natural hazards are also discussed.A range of mitigation measures is available including reforestation through the improvement of land management practices have been proposed. The paper also sets priorities in flood protection to focus on monitoring and surveillance of flood situation, simple measures for flood mitigation, disaster management and the operation and maintenance of flood management works. Specific measures that should instituted in relation to policy, legislative and institutional reforms, and capacity building including formation of national and regional flood management boards that specifically deal with natural disasters are also presented. Wealth creation and poverty alleviation are issues must be given prominence in the economic recovery strategies for all governments in the basin.

Keywords: Lake Victoria basin, natural disasters, floods, drought, vulnerability, disaster management, disaster preparedness, early flood/drought warning system

BACKGROUND

The major forms of disasters include droughts, floods, terrorism, landslides, HIV/AIDS and disease epidemics, transport accidents, fires/industrial hazards and pollution. There are other extreme outbreaks of diseases, such as cholera, malaria, typhoid and meningitis, which have become threats and may be classified as disasters. The focus of this paper is on natural disasters, which are rampant within the Lake Victoria basin and are related to extreme weather and climate events such as droughts, floods and strong winds, among others. Extreme weather and climate events influence the welfare of the society and entire economy of the region with droughts and floods having the highest adverse effects. The sectors that experience the immediate effects include agriculture, health, and water resources among others.

Droughts and floods contribute to the most devastating natural hazards in the basin, which often translate into disasters in the riparian countries. Droughts affect food production, availability of water, and generation of hydroelectric power for industrial and domestic consumption. The majority of short falls in food supply recorded in 1928, 1933-34, 1937, 1939, 1942-44, 1947, 1951, 1952-55, 1957-58m 1984/85 and 1999-2000 in Kenya could be easily associated with rainfall deficits experienced in the respective years. The intensity, duration and total magnitude of the rains are some of the key factors affecting agricultural production in the basin. The droughts may also lead to outbreak of some unique diseases including those related to water scarcity and contamination.

On the other hand, floods lead to the displacement of communities, and destruction of the infrastructure and crops. Like droughts, they also lead to outbreak of diseases. Floods are attributed to the heavy rainfall over the catchments upstream; rivers often burst their banks and submerge the neighbouring

farms and houses. This results in displacement of people, destruction of homes, granaries, farmlands, road network, schools and grazing land. Most of the displaced families move to higher grounds where they put up in makeshift camps. The state of water supply and sanitation is very bad for the community affected in addition to the increased density of mosquitoes due to the stagnant water resulting in an upsurge of water borne diseases.

Droughts differ from other natural hazards in several ways:

- Slow-onset, creeping phenomenon that makes it difficult to determine the onset and end of the event;
- Duration may range from months to years;
- No universal definition;
- No single indicator or index can identify precisely the onset and severity of the event;
- Impacts are generally non-structural and difficult to quantify;
- Spatial extent is usually much greater than for other natural hazards, making assessment and response actions difficult, since impacts are spread over larger geographical areas;
- Impacts are cumulative.

STATUS OF LAKE VICTORIA ECOSYSTEM, INCLUDING DRIVERS AND PRESSURES RELATED TO FLOOD DISASTERS

The vulnerability to flood disasters is a function of a number of physical features and social characteristics. The physical features associated with maximum vulnerability of flood disasters in the basin include:

- The marginal hydrological and climatic regime;
- High rates of sedimentation leading to reduction of reservoir storage;
- Topography and land-use practices that promote soil erosion and flash flooding conditions; and
- Deforestation, which allows increased surface runoff, increased soil erosion and more frequent significant flooding.

The social characteristics that increase vulnerability to flood disasters include:

- Poverty and low income levels that prevent long term planning and provisioning at the household level,
- Lack of water control infrastructures,
- Inadequate maintenance and deterioration of existing infrastructure,
- Lack of human capital skills for system planning and management,
- Lack of appropriate and empowered institutions,
- Absence of appropriate land-use planning and management,
- High population densities and other factors that inhibit population mobility,
- Increasing demand for water because of rapid population growth, and conservative attitudes toward risk, i.e. unwillingness to live with some risks as a trade-off against more goods and services.

It should be noted that flooding poses serious threats to pollution of both surface and ground water resources in an area. The key indicators of vulnerability and risks in the water resources sector as mentioned earlier can be grouped as both natural as well as human-related factors. The major drivers leading to flooding include climate, topography and geology while the human-related factors include settlement patterns, land-use patterns and pressures, migration patterns, population pressure, degradation of water catchment areas, unsustainable water supply, poverty and access to health and social services. These are briefly discussed in the sections below:

Climate

Of all the relevant factors in climate, precipitation is the main cause of disasters in the water resources sector. Abundant precipitation can lead to disasters such as flooding, water pollution, soil erosion, dam breaks as well as water-related disease outbreaks and famine. On the other hand, scarcity of

precipitation in areas, which ordinarily receive it, can lead to drought, water scarcity, loss of vegetation, loss of livestock and wildlife, famine and general suffering of people living in the affected areas. It is important that the characteristics and predictive potential of rainfall is factored in all the water resources management practices and policies in order to mitigate the adverse effects of disasters. The low altitude areas of the Lake Victoria basin experience two major rainfall seasons, March – May (long rains) and October – December (short rains). The "long rains" are the most reliable in the low altitude areas of the basin. The neighbouring highlands have rainfall almost throughout the year with the peaks in March – May, June – August, and October – December.

It is estimated that 85% of the water entering the lake does so from precipitation directly on to the lake surface, the remainder coming from rivers which drain the surrounding catchment (UNEP 2004). The most significant of these rivers, the Kagera, contributes roughly 7% of the total inflow. Some 85% of the water leaving the lake does so through direct evaporation. The remaining 15% leave largely by way of the Victoria Nile, which leaves the lake near Jinja in Uganda, and flows via the Owen Falls, Lake Kyoga, and the Murchison Falls to join the outflow from Lake Albert.

Although human impacts on the lake basin environment may now eclipse the events taking place, climate factors could be reinforcing environmental degradation in the lake basin. In the case of the Nyando River Basin in Kenya, interviews with local people suggest that many of the major soil erosion problems either started or were dramatically accelerated in their development during the early 1960's. Prevailing conditions during the early 1960's may then have been such that the basin was essentially primed for massive erosion/sedimentation during a period of extraordinarily heavy rainfall in the region. This is of particular concern as we can only speculate what might happen now, should we witness the return of a rainfall period of the magnitude observed during the 1960's.

Geology and Topography

The geological characteristics of an area are known to influence the drainage patterns, the nature of soils as well as land use patterns. For instance, heavy rainfall is more likely to cause flooding in low-lying regions occupied with clay formations because clay formations have low infiltration capacities and therefore surface runoff is generated rapidly. The same heavy rainfall in zones occupied by sandy soils will not cause significant flooding since rapid infiltration of rainfall reduces the likelihood of generation of high volume of surface runoff.

The topography of a region also determines land-use patterns as well as the patterns and intensity of erosion and landslides. It influences the gradient of rivers such that in areas with steep slopes, water flows rapidly into river channels. In such cases, the flood stage of a river is reached rapidly. In flat plains, the gentle slope reduces the velocity of flow leading to formation of meanders and flood plains. Water in such areas is not transported rapidly and tends to pile up making the low-lying zones more liable to flooding such as in Kano plains of Kenya.

Population Pressure and Settlement Patterns

Settlement patterns are partly influenced by population pressure. In urban areas there is tendency for the slums to develop in areas, which have been designated as flood-prone zones. Settlement on steep slopes as well as cultivation on such lands also tends to increase the vulnerability of the community to landslides. This also increases possibility of increased rates of soil erosion particularly where overgrazing and deforestation have reduced vegetation cover. Modification of river channels through channel straightening can lead to rapid flow of water into streams thus promoting rapid increase in water levels in rivers. Flooding of the low-lying areas often follows this.

High Population Growth

The Lake Victoria basin (LVB) now supports one of the densest and poorest rural populations in the world, with densities up to 1200 persons per square kilometre in parts of Kenya (Hoekstra and Corbett

1995). The first systematic population surveys for Kenya, Tanzania and Uganda, were conducted during the late 1940's. The 1948 estimate for Kenya, for example, is given at 5.7 million inhabitants (Lury 1969). The current estimate is 28.4 million inhabitants giving an approximate population doubling time of 22.1 years. This means that the population of Kenya has doubled approximately 3.3 times in the time required for the water in Lake Victoria to turn over once. Moreover, population densities in the lake basin portions of Kenya, Tanzania, Uganda, Rwanda and Burundi are well above their respective national averages, indicating doubling times that are probably considerably shorter than the respective national averages.

National population growth rates, though declining due to the HIV/AIDS pandemic and other diseases, remain among the highest in the world and the populations in the five riparian countries are expected to double again over the next 25-35 years. More specific projections and scenarios for Lake Victoria basin will be needed in order to provide realistic 2050 land and water degradation scenarios based on which various management and policy options could be evaluated.

Poor Land-use and Degradation of Catchment Areas

Poor land-use activities characterized by deforestation and clearance of bushes and other vegetation is the major cause of catchment degradation. Cultivation on steep slopes without applying soil conservation measures promotes soil erosion and rapid generation of surface runoff. Vegetation cover is essential since it retards the flow of surface runoff thus encouraging more water to infiltrate into the soil and replenish soil moisture. The recharge of groundwater aquifers also takes place through infiltration and deep percolation of rainwater. Other causes of the degradation of catchment areas include poor construction of roads and footpaths, which are sources of sediments carried by the surface runoff to river channels. Lack of effective urban planning mechanisms promotes development of slums and other residential structures which discharge sewage and domestic wastewater into river channels thus degrading important water catchment areas.

The land use within the basin is primarily small-scale subsistence agriculture and large-scale sugar cultivation in parts of Lake Victoria basin in Kenya. Subsistence crops include Maize, Sorghum, Pulses and Tuber crops. In the plains Cotton is grown and Rice is grown further downstream. Livestock raising is also a main agricultural activity with large areas left for pasture. One of the critical factors affecting land-use management is land tenure. The residence period of land users on a particular piece of land could influence their attitudes towards good land-use practices, which could promote environmental conservation. Generally land in Kenya is either under customary tenure, freehold, leasehold, and trust hold or government land. The impact of each of the tenure systems depends on land-use activity.

In many parts of the basin especially in the flood prone areas, there is large-scale destruction of forests and watershed degradation due to unscientific and unregulated land use causing increased flood hazard over the years. Heavy sediment loads brought down by rivers from denuded hilly catchments and consequent aggradation of the river beds in lower reaches decrease the carrying capacity of the rivers and consequently generates rise in flood levels. Most farmers engaged in agriculture in steep hill slopes violating the relevant provisions of the Agriculture Act.

Excessive encroachment of the "river reserves" by the people and "overstocking" of livestock far in excess of the carrying capacity of the land, and climate changes are also seen as the factors contributing to increased flood hazard. Both the government and the people are to blame – the government for lack of seriousness and coordination in dealing with hazard and people for lack of awareness and slow response to the situation.

Lack of Regulatory Systems

The enforcement of regulations governing settlement in zones designated as flood-prone has been a major problem in the riparian countries in that the enforcement is weak partly due to weak institutional capabilities to enforce regulations. Similarly, there is no effective co-ordination between different government departments and non-governmental organizations resulting into wastage of resources and

duplication of effort. The uneven development in the country particularly the huge difference in the living standard of urban and rural areas are encouraging the influx of rural poor into urban areas in search of better opportunities.

This has lead to overcrowding in urban areas, severely over-straining the existing housing, health, water supply, sewage, and educational and recreational facilities. Most of the present facilities in urban areas were designed to carter for a small elite population during colonial times. Lack of housing and inability to access more decent housing has encouraged development of slums in areas, which are more liable to flooding. This makes the urban population around the lake more vulnerable to flooding.

Poverty

Poverty encourages people to dwell in slums located in flood-prone zones of the urban areas. It has also contributed to the limited application of better land-use practices and soil conservation methods in rural areas. Cultivation in these areas is thus done by using unsustainable indigenous technology, which provides low yields and exposes soil to erosion hazards. Also, it has encouraged the conversion of swamps and wetlands into settlement and agricultural lands thus subjecting the population to the risks of flooding.

High Levels of Poverty

Lake Victoria directly or indirectly supports 28 million people who produce an annual gross economic product in the order of US$ 3-4 billion (or 107–143 $US GEP per capita). Over the 1965-95 period growths in per capita income levels in Kenya, for example, averaged 2.4% ± 2.6% (95% CI) per annum (World Bank 1998). Even at the most optimistic end of this range (i.e., 5% growth per year), income doubling from 386 US$ (in 1995) to 772 US$ per capita would be expected to take about 14 years. Under prevailing economic conditions, such a scenario seems highly unlikely, and even if it were to occur, Kenya would still rank in the lowest third of countries on a per capita income basis by current standards.

In Kenya for example, the Welfare Monitoring Survey implemented in 1994, showed that the incidence of “hard core” poverty was between 40% and 50% in three Lake Basin districts (Bungoma, Busia and Kericho) and between 30% and 40% in four Lake Basin districts (Bomet, Nyamira, Vihiga and Kakamega). Hard core poverty was defined as total expenditure of less than Ksh 703 per adult equivalent per month (Central Bureau of Statistics 1998) and is thus a much stricter standard than the dollar-a-day rule used by the World Bank. It is currently unknown how these figures will project to the future in a lake basin-wide context, and there is thus a need to collate income as well as other relevant poverty indicators in other parts of the basin. Unfortunately, most such statistics are compiled at the national-level, and are generally difficult to disaggregate toward sub-national entities.

The main occupation of the flood plain dwellers is agriculture, livestock farming and fishery. Due to poor quality inputs and unscientific techniques being used in these occupations the income levels are low. Market access for the products is hampered due to poor road network and condition of roads, but to a large extent due to poor marketing mechanism. Subsistence agriculture, pastoralism and agro-pastoralism support about 21 million people in the basin (est. from data by Deichmann 1994) with average incomes in the range of US$ 90-270 per annum (World Bank 1998). In view of the pervasive poverty among farming communities in the basin, the use of inorganic fertilizers is limited, and primary productivity is closely linked to the inherent productive capacity of the soil. It is unlikely that fisheries, subsistence agriculture and extensive (agro)-pastoralism in their current forms will be able to support food and income requirements under the projected population doubling scenario over the next 25-35 years. Substantial investments in market infrastructure, roads, soil fertility recapitalization, education, fisheries management, conservation and human and veterinary healthcare will be necessary for sustainable intensification and economic growth in the region.

Limited Access to Proper Health Care and Social Services

Poverty has also made it difficult for a large percentage of the urban and rural people who lack access to medical facilities. This has promoted high morbidity caused by water-borne and water-related diseases, which are otherwise treatable. This is worsened by the inability of the government to provide highly subsidized access to public health facilities. Lack of an effective public health system is making people more liable to epidemics associated with the occurrence of extreme climatic events such as floods and droughts.

Lack of social amenities in both rural and urban areas is also thought to contribute to the low level of preparedness of the local population to handle disasters. This is particularly so given those facilities for dissemination of information to the general populace are often inadequate or completely lacking in certain areas. Thus community mobilization is a difficult task, which is not easily achievable in periods of emergencies.

Poor Communication Infrastructure

Availability of good communication and transport network is essential in the management of disasters. These include telephone links, roads, railways, airports and airstrips. These are essential for evacuation of people during periods of emergencies. However, the current telephone network is poor and most rural areas are not linked to an efficient telephone system. In addition road and railway network in most places is not in good condition and thus access to zones, which are usually affected by droughts and floods, is problematic.

The present telephone and road network was designed to carter for much smaller population. This has worsened the problem of communication. Road traffic has increased tremendously in the recent past leading to rapid deterioration of roads, which were designed to take much smaller loads. Thus lack of access to reliable communication network has increased the risks and vulnerability of the population to extreme climatic events since the affected population cannot be mobilized rapidly. It should be noted that quantification of the vulnerability of the society is quite complex especially when estimating cumulative stresses induced by inter annual variability and long-term climate changes. It will require multiple indices representing the different aspects of vulnerability including the coping mechanisms and adaptive capacity, hazards exposure, ecosystem sensitivity, land use and land use changes. The state of the current climate is however critical in planning the basic coping and adaptive capacities.

IMPACT OF FLOOD DISASTERS

The direct impact of floods are discussed in general terms such as loss of human lives and livestock, damage to standing crops, loss of personal property and damage to rural infrastructure. Indirect impacts are classified as loss of income, disruption and set back to on going development programmes, outbreak of water and vector borne diseases during and after floods, disruption of normal family life. The problems of women, children, old and the infirm are clear impacts. The women are invariably over-worked since they have to manage the usual domestic chores under sub-normal conditions in the relief camps. The most physically stressful tasks are those of fetching water and firewood and taking care of the ailing members of the family – often ignoring their own morbidity.

The stressful conditions in the relief camps are deepened by other social vices including sexual abuse of women by anti-social elements, exploitation of children through child-labour and general neglect of the old and infirm. The criteria of distributing relief supplies to family as a unit may perpetuate child marriages. Segregation of family members is as one of weaknesses of the relief operations during flood emergencies. There are, however, certain beneficial effects of flooding such as improved soil fertility and increased availability of fish in the river and flooded areas. It is still unclear how the prevention of flooding and the benefit of increased fish harvest could be harmonized.

Environmental impacts of floods can be grouped under the following main categories:

(i) Pollution of wells and bore wells
(ii) Bank erosion
(iii) Lateral shifting of river channels
(iv) Silting of river beds
(v) Loss of top soil (soil erosion)
(vi) Displacement of wildlife
(vii) Destruction of natural vegetation
(viii) Wanton cutting down of trees for fire wood around the relief camps

Vulnerability of People to Floods

"Cultural attachment" of the lake basin dwellers to the land and their unwillingness to move to safer places can be an avenue for vulnerability to floods. Poverty and lack of awareness about options for enhancing income, and lack of early flood warming system at the village/community level are key factors contributing to their vulnerability. Fishermen, in particular, are the most vulnerable since their occupation requires them to live close to rivers and flood plains. Box1 indicates the flood situation in Budalangi (Kenyan side of the basin) during May 2003.

Box 1: Case of Budalangi floods in May 2003

Ironically, local downpours do not cause most of the floods in Budalangi. Rather it is the heavy showers upstream, which are then carried down to the plain from Mount Elgon by the Rivers Nzoia and Yala. The water carried by the two rivers from areas as far away as Trans Nzoia, Uasin Gishu and the Western Region of Kenya is meant to flow into Lake Victoria. During flash floods, Lake Victoria is slow in absorbing the excess water, and instead sends it back, imprisoning the inhabitants of flat areas like Budalangi.

The entire homesteads were swept away, residents and animals displaced, property and crops worth hundreds of thousands of shillings were lost and many people perished as rivers broke their banks, rendering large areas of land inaccessible. The floods created poverty, because crops and businesses were destroyed. The contamination of pipes and bore-wells aggravated an already acute problem.

The region's already battered infrastructure became further dilapidated, with schools being submerged, thereby disrupting the education of many children. Those schools that were not affected became heavily congested. Out of Budalangi's population of 53,000, nearly 25,000 were displaced. Some 10,000 of them were accommodated in the District Officer's camp, necessitating health emergency measures to control possible outbreaks of malaria, bilharzias, cholera and other water-borne diseases.

INTERVENTIONS

A range of mitigation measures is available:

- Flood protection measures like construction of dykes, installation of a flood warning system, resettlement and construction of a reservoir;
- Protection of springs and shallow water wells, increased coverage of urban and rural domestic water supply and sanitation services, development of new supplies and reduction of losses in the distribution systems are measures that can be taken to correct the inadequate water supply and sanitation, and;
- Reforestation through the improvement of land management practices, zoning of conservation areas for protection, improving quality sampling frequencies, setting up and recommending standards for

effluent discharges to be maintained by industries, proper application and use of fertilizers and pesticides as measures that can remedy the environmental degradation problem.

Priorities in Flood Protection

Establishment of accurate and early warning system with linkages up to the community levels is the first priority option in flood management. Equally important is the preparation of contingency plans for evacuation and relief measures. Land use regulation through legislative and administrative measures to reduce and regulate use of flood plains for various economic activities. Among the structural measures, construction and maintenance of dykes and drainage channels are top priority options. Afforestation and "conservation" of catchments, development of pastures and land use regulations are measures that can reduce flood discharges in rivers.

Monitoring and Surveillance of Flood Situation

The following action points can also be considered:

- Intensification of hydromet data collection;
- Setting up early warning system at the community level;
- Situation analysis;
- Intervention;
- Monitoring and evaluation;
- Dissemination of information to all stakeholders;
- Establishing teams to monitor climatic changes and water levels in rivers;
- Identifying vulnerable points in the dykes;
- River gauge readers to be trained to explain the significance of water level to the community;
- Dyke management committees to be charged with the responsibility of bush clearance, identifying weak spots and repair of dykes and regulation of floodgates.

Simple Measures for Flood Mitigation

Some of the efforts that do not require a lot of investment but only mobilization and coordination include:

- Removing of bushes from dykes. This can pay high dividends because bushes cause cracks and seepage. In the absence of strong dykes, emphasis ought to be placed on disaster preparedness through contingency planning measures.
- Training and sensitization of the people in rescue efforts and understanding early warning climate systems, so as to inform residents to move to higher grounds before the floods hit, are critical contingency plans.
- Preparing qualified medical personnel, drilling bore holes for safe drinking water and ensuring that sanitation is of a high standard and properly maintained to check for disease outbreaks. It is up to the Ministry of Works to ensure that roads are passable, since this can be a big impediment during rescue efforts.
- It is during such floods that food scarcity becomes critical. However, the residents need to be educated to plant short-term crops or crops that can withstand floods. It would be prudent to relocate schools to temporary shelters in other areas to maintain learning continuity and minimize congestion during flooding.
- Floods can be conquered if all stakeholders work together in pushing through effective long-term strategies.

Disaster Management

There is need to empower the Disaster Management Committees with necessary skills, equipment and financial resources, and to stockpile emergency supplies at strategic locations. The communities should

be able to act on receipt of advance warning, and should, therefore, be supplied with communication equipment and dedicated transport arrangements for quick evacuation. Their participation in camp committees to oversee sanitation, general welfare of the people and distribution of relief supplies and safe drinking water, should be supported.

Operation and Maintenance of Flood Management Works

The responsibility of operation and maintenance of flood management works should be transferred to the local communities who should form management committees for the purpose. The community groups should be given training in operation and management and provided with appropriate communication equipment.

POLICY, LEGISLATIVE AND INSTITUTIONAL REFORMS AND CAPACITY BUILDING

Certain measures can be instituted in relation to policy, legislative and institutional reforms, and capacity building. These include:

- Review of existing legislations to ensure that they are not top-down, and do reflect the views of the target group (community);
- Provision, in simple language, of relevant legislation to communities;
- Participatory approaches at all stages of planning, implementation, monitoring and evaluation, and the roles and responsibilities of all stakeholders should be clearly defined to avoid duplication of effort;
- Involvement of the community in data collection, post disaster response and implementation of recovery and mitigation plans;
- Enhacing of the knowledge base and capacity of NGOs and CBOs through training programmes;
- Formation of National and Regional Flood Management Boards that specifically deal with natural disasters;
- Establishment of disaster contingency fund(s), and;
- Allocation of funds for maintenance of dykes.

FLOODS: OPPORTUNITY FOR ECONOMIC PROSPERITY?

Economic power is the ability to purchase food, stay healthy and live in comfort. Floods are known to cause food shortages, malnutrition, diseases and other economic hardships. The economic hardships brought about by floods do result in poverty to majority of the affected communities. Wealth creation and poverty alleviation are issues given prominence in the economic recovery strategies for all governments in the basin.

It has been highlighted that poverty in the flood prone areas is high. Every little effort made by communities in the flood prone areas to improve their well-being is normally swept away by floods, which have become more frequent. It is internationally agreed that the economic base of an individual can influence his vulnerability to natural disasters. A strong economic base improves the resistance of an individual to natural disaster. Hence, in addressing the flood-related disasters in the affected areas, attention must be given to wealth creation.

The economic activities of the communities in the flood prone areas within the basin include fishing, crop farming and livestock farming. Crop farming is disrupted in a flood situation since the crops grown in most areas are those that cannot be sustained in floods. Efforts should be made to convert the floods into productive crop fields by introducing crops that can survive the floods. The animals are often shifted to dry areas during flooding. However, livestock farming is not a major engagement of the communities in the flood prone areas. The herds are small and not economical. The flood plains are also important for pastoral activities since the fertile lands in the plains are good for the development of abundant pasture. The livestock farming therefore needs to be promoted by introducing the breeds that can withstand the flood conditions and are economically productive.

Fishing forms the major economic activities in the flood prone area. It has been observed that fish becomes more abundant during floods. The abundant fish is good for providing protein to households during a flood disaster. However, since floods destroy roads and fish landing bays, the available fish are only consumed in the camps. They do not reach the market due to poor road infrastructure and lack of storage facilities.

The proposed wealth and poverty alleviation strategies that would reduce the vulnerability of the communities to floods should include strategies to:

- Enhance the fishing industry by improving the fishing gears, providing storage and improving the road infrastructure;
- Improve the fish farming in the affected areas;
- Introduce horticultural farming as well as new crop varieties that cannot be affected by floods;
- Encourage horticultural activities in the flood prone areas;
- Encourage afforestation and agro-forestry to provide wood for use and for commercial purposes, and;
- Encourage livestock farming by introducing breeds that are adaptable to the climate of the regions and are economically viable.

STRATEGIES FOR DROUGHT MITIGATION

Droughts are part of the climate system and are therefore not preventable. However, drought disasters are preventable. Coping with drought hazards can be developed through adequately addressing the answers to the following three questions:

- How frequently or extensively does a certain type of drought occur in a given region?
- What are the vulnerabilities and expected losses, which are associated with that type of drought?
- What are the costs for implementing the plausible strategies or options for mitigating the disaster that can be caused by that type of drought?

Strategies and drought mitigation options that are set to address the above questions involve integration of a wide spectrum of drought issues such as enhanced drought monitoring, drought research and forecasting, drought risk and vulnerability assessments, capacity building, drought awareness and education and dissemination of drought information. The use of such strategies aims to reduce vulnerability of the drought prone communities by either altering their land use practices or by modifying the drought severity through provision of the required water supplies for food production or through the implementation of relief programmes that enhance water and food securities on both short and long-term basis. The slow onset of drought combined with drought forecasting capabilities also enables the implementation of contingency plans and measures in advance of the occurrence of the drought. The improvement in recent years in the seasonal and long-term climate predictions, such as those issued by many national and regional institutes in Africa, including the Drought Monitoring Centres have assisted in the implementation of drought disaster mitigation and effective contingency plans.

There are many other types of drought coping mechanisms. Some of these that have been found to be important in drought-coping include:

- Encouraging the use of drought resilient crops;
- Strengthening land tenure policies to discourage settlements in marginal lands;
- Revival of traditional customs, traditions and land-use practices that are important in the mitigation of the severity of droughts; and
- Relocation of communities to other areas, which are less drought-prone.

Early warning for floods and droughts

Before the advent of modern scientific methods, some communities around the lake realized that some animals, birds, insects and plants had the capacity to monitor and detect the changes in the atmospheric conditions and learnt their behaviours as a way of predicting the future climate.

Traditional methods

The populations with low-level technological cultured development learnt much from the behaviour of plants, animals and insects with high body sensitivity and instincts. They also mastered the positions of stars, the sun and associated shadows and the moon, the wind strength and direction and the cloud position and movement and the lightning patterns. The knowledge about past disasters and climate in the region are the accumulated experiences that have been handed down to generations through oral traditions. Due to the importance of weather and climate to the communities around the Lake, the communities have developed traditional methods for monitoring and predicting weather and climate. The sailors have also to master the winds over the Lake. In the ancient times these communities also believed in “rain making” and capability to influence lightning as an inherited and spiritually provided talent.

Traditional indicators among the Luos

Among the Luo community, the rainfall indicators used include plants, animals, insects, wind, clouds, temperature, stars, the moon, and wetlands (thidhya). Some of the indicators and their signs are listed below.

Plant indicators

- Manera (*Terminalia brownii*) is a tree, which normally grows very big and sheds the leaves to signal dry conditions.
- Ngowo (*Ficus sur*) sheds its leaves twice a year.
- Waa (*Tamarindus indica*) also drops/sheds its leaves twice a year.
- Yago (*Kigelia africana*) drops/ sheds off its leaves thrice a year.
- Ober (*Albizia coriaria*) sheds its leaves once a year.
- Saye (*Acacia gerrardii*) sheds its leaves twice a year.
- Bongu (*Ficus ovata*) sheds its leaves twice a year.
- Opok (*Terminalia mollis*) sheds its leaves once a year.
- Amboro sheds its leaves twice a year.
- Juelu sheds its leaves twice a year.
- Olemb-ajwa and Olemb-ochok have flower blooms twice a year.
- Ruga sheds its leaves once a year.
- Ochuoga (sheds off its leaves twice a year showing both long and short rain seasons)
- Siala sheds its leaves thrice a year.

The shedding of leaves is an indication of water stress associated with dry conditions. The trees shed the leaves to reduce evapotranspiration and would grow leaves when the rains approach. Some plants used to monitor seasons include:

- Otonglo seasonal plants are available during wet/ rainy seasons and Ayila/Aila plants are very abundant during the long rains/ wet season, and are also common along the riverside or hilly bushes. The Ayila plants are only in abundance during the long rainy seasons and appear for a short time during short rainy season.
- Ruga - falling of white flowers.
- Yuoma (*Erythrina excelsa*).
- Orembe – when it starts shedding off red flowers, the planting season would commence because the wet/ rainy season is just about to start.
- Oluoro chieng’ (a shrub) as the name suggests occurs only during wet/ rainy season and dries up quickly during dry season.
- Awayo eaten by children who are grazing livestock is also seen only during rainy season.

- Maup-pap (Rhamphicarpa) commonly found in Angugo plain and between Ong'oche and Othoch-rakuom and between Nyatike and Ong'er comes up with the slightest sign of rain.
- Anyim, the seed may stay in the soil for years when the rainfall is not sufficient for it to grow.
- Nyalwet-kwach is a shrub, usually used as medicinal plant, but is disappearing first because of burning of forests. Kasigo-jaleny-thee (is a plant which share the name with oil pot) and Odo-do are also sensitive to dry weather and dry up early even before the rain disappears completely.

Insect indicators

- The presence of Aguyo (butterfly) is an indicator for drought continuity.
- Safari ants also acting as an indicator of seasonal change carry food and store it just before heavy rains start.
- Chwer ng'wen (termites) showed the reduction of rainfall and the approach of drought.

There are five types of army ants (Ngini-ngini) that are used as indicators. They include:

- Katalang' – black large poisonous ants
- Tho-morno – red large ants
- Omonyio – medium size ants rather harmless
- Ong'ino – small red ants
- Ong'ind kombe kombe – the large dark red tree ants.

These ants' movements are good indicator of wet/ rainy season approaching and when transporting food or their eggs is a clear indication of the closeness to a rainy season. However, there are controversies on the particular season the ants transport their food and eggs.

- The presence of Agoro ants signals a sign of continuous rain season.
- The appearance of Oyala ants sometimes shows no rains on that particular night; however, rains are still falling.
- The appearance of Onyoso ants showed continuity in rains.
- When Kungu (Armyworms) appear, people long for rain, which would normally make them grow quickly.

All the above are known insects associated with rains or wet season. When dry season approaches only ants and butterflies are seen frequently.

Wind, clouds and temperature

The direction and strength of wind is used by the communities to mark the beginning of rains and possible performance. The whirlwind (Kalausi - in Nyanza) is a clear indicator of approaching wet season. However, strong easterly winds (Komadhi) marks dry spell and in years when it sustains itself beyond March the communities in the Lake Victoria basin expect a poor March-May rainfall season.

Modern Methods

Forecasts of hydrological hazards such as widespread flooding are increasingly based on computer modelling. The use of hydrological models can enhance the understanding and prediction of flood hazards in the basin. However, most of these models are for design purposes and must be adjusted or tuned for use in real-time flood prediction. This is far from being a reality in the basin. Attempts have been made to use seasonal rainfall forecasts to identify areas of either significantly above-normal seasonal rainfall or areas, which are likely to receive heavy episodic seasonal rainfall to identify the flood-hazard prone areas in the region during the given season.

For drought, prediction is still heavily reliant on monitoring of observed patterns of monthly and seasonal rainfall, stream flow, reservoir and ground water levels, and soil moisture. Widespread drought evolves relatively slowly when compared with floods and may persist for months or years and it can be difficult,

if not impossible, to predict its end. During drought situations, it is difficult to implement many remedial actions and those measures, which can be taken, are often site and situation specific. Statistical approaches are more relevant for the development of predictive tools for large geographic regions on monthly and seasonal time scales. Statistical techniques offer promise for increasingly useful forecasts of the onset, severity and duration of drought. Ochola and Kerkides (2003) used first-order Markov processes to estimate critical wet and dry spells in Kano plains while Ogalo and others (2000) presents the possible application of climate variability to agricultural planning and operations including avoidance of drought and rainfall (flood) hazards. The potential benefits of accurate forecasts on these time scales are evidently enormous.

Purpose of forecasting for flood control

Forecasts should be timely

- So that there is enough time to evacuate people from the possible flood areas
- To enable the heightening and reinforcement of dikes, dams and other flood control structures in the lower reaches of a stream well in advance
- To make rational dispatch of the reservoirs, to release water from the reservoir storage or interlock the flood peaks in lower reaches, so as protect flood control structures and ensure flood discharge in the lower reaches of a stream
- To have enough time to send flood control materials and emergency squads to the areas prone to flooding
- To have enough time to check flood control equipment in the cities and to clear the obstacles in the flood paths of the lower reaches of a stream.

CONCLUSIONS

Some major pressures on the lake environment which lead to natural disasters include high population growth rate, poor land use practices, high rates of sedimentation arising from poor land use practices, changing rainfall patterns. Climate information and products form an important component for disaster reduction and sustainable socio-economic development in the basin. Climate extremes are recurrent and the only way to reduce impacts is to reduce risks through enhanced preparedness and improved economic base of the communities. Early warning systems for specific disasters should be put in place and the modern methods should integrate traditional methods. The capacity of the communities to utilize early warning information should be strengthened. Environmental protection through proper land use practices must be encouraged and relevant policies that protect land degradation must be enforced. Communities need to be sensitized that disasters can be turned into economic gain other than viewed as a calamity.

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Conflict over Transboundary Fishery on Lake Victoria and its Management

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ABSTRACT

The Nile perch fishery on Lake Victoria has become a highly demanded commodity because of its commercial value at the international market. The increased demand and declining fish stock of the Nile perch fish has led to conflicts or disagreements (starting 2001) about access to and/or control of better fishing grounds. The conflicts arise among fishers in the course of their interaction on the fishing grounds and between fishers and the law enforcement authorities as they try to control fishers movements across-border as they look for better fishing grounds and markets in disregard to the laid down rules and regulation of the respective countries. The paper explains the reasons behind conflicts over transboundary fishery on Lake Victoria as well as a long-term strategy being initiated to address them. It demonstrates that capacity building at the local level through the regional institutional framework on Lake Victoria is the best approach to address challenges arising from a dynamic transboundary fishery. It presents the experience of the Lake Victoria Fisheries Organization (LVFO) and IUCN - The World Conservation Union in understanding and managing the conflict over transboundary fishery on Lake Victoria.

Key words: *Lake Victoria, conflict, fishery, transboundary fisheries management, beach management unit*

INTRODUCTION

Lake Victoria is Africa's largest freshwater lake, shared by the three East African Community (EAC) Partner States, Kenya (6%), Tanzania (51%) and Uganda (43%). The greatest development challenges facing Lake Victoria basin are its socio-economics and ecological problems, with a close correlation between poverty and environmental degradation. The ecosystem of Lake Victoria has undergone substantial negative changes over the last thirty years and one of the driving factors is the nutrient enrichment of the lake, which has altered its ecological balance. The Lake and its natural resources are environmentally threatened and so are the livelihoods of the people living in the catchment area. Intense population growth and unsustainable exploitation of the natural resources in and around the lake are eroding the livelihoods of the people. Environmental deterioration is increasing poverty, and poverty is exacerbating the environmental degradation. About half the population has an income per capita of less than one US dollar per day, the internationally accepted poverty line (Sida 2003).

Its highly productive fisheries of about 500,000 metric tones per year supports a significant proportion of the basin's 30 million inhabitants and makes substantial contributions to the national economies of the Partner States through export earnings valued at US$ 600m annually (LVFO 1999). The fishery of Lake Victoria consists of 3 major commercial species namely, Nile perch, tilapia and dagaa (*Rastrineobola argentea*).

Though highly productive, Lake Victoria fishery is faced with a number of threats and challenges among them decline in fish catches; deterioration of fish habitat; excessive fishing efforts; use of destructive fishing gears and methods; absence of fully harmonized fisheries regulations among the Partner States as well as non-uniformity between the Partner States in who the law enforcement authorities on the lake are; and inadequate institutions and institutional processes especially at local level for the involvement of local people in fisheries management. Acknowledging all these and the fact that Lake Victoria is a

shared resource, the Partner States in 1994 formed the Lake Victoria Fisheries Organization (LVFO) for the joint management of the Lake Victoria fisheries.

Since 2001 there has been an upsurge of conflict over transboundary fishery on Lake Victoria, an issue that has become the most immediate obstacle to fisheries management on the lake. The LVFO with the technical assistance from IUCN through the *Socio-economics of the Nile perch fishery project phase II* has investigated the issue and developed a long-term strategy for its management.

BACKGROUND

The Nile perch fishery on Lake Victoria has become a highly demanded commodity and as a result access to it and/or its control and use has become an issue of economic importance giving rise to the establishment of more than 30 fish processing plants on the shores of Lake Victoria. Fishing effort has increased, for example in 1980 there were 30,000 fishers and by 2000 the number had gone up to 120,000. This development in the fishery sector poses new challenges for fisheries management such as declining fish catches (especially Nile perch), increased capital investment in the fishing sector, improved mobility of fishers and increased fish processing capacities (Heck and others 2004). The increased demand and declining fish stock have led to conflicts or disagreements about access to and/or control of better fishing grounds. The conflicts arise among fishers and between fishers and the enforcement authority as the authority try to control fishers cross border movements in search of better fishing grounds and markets which they do without observing the applicable fisheries and immigration regulations of respective countries.

Cross border fishing in search of better fishing grounds as well as the smuggling of fish across borders in search of better markets has been going on for many years virtually undisturbed until the late 1990s. The conflicts between fishers and enforcement authority manifested themselves when the Partner States strengthened their Monitoring, Control and Surveillance (MCS) to control the smuggling of fish as well as cross border fishing to ensure that their economies benefit from the trade. The conflict came to a peak in 2001 when the issue evolved from a fisheries issue to a political issue. In September 2001 the LVFO convened a meeting of the heads of the fisheries departments of the three Partner States to come up with a solution to the conflict. The implementation of the immediate measures by the LVFO Council of Ministers made on June 28th 2002, reduced the intensity of the conflict, but further efforts were needed for a lasting solution.

It was on this basis that the LVFO with the technical assistance from IUCN through the *Socio-economics of the Nile perch fishery project phase II* investigated the issue and developed a long-term strategy to manage the cross-border conflicts.

THE CONFLICT OVER TRANSBOUNDARY FISHERY ON LAKE VICTORIA

Whereas the political and legal responsibilities at all administrative levels in the three EAC Partner States are well understood and adhered to, and whereas cross-border co-operation in many aspects is strong, a mobile natural resource such as fish knows no man-made boundary and consequently migrates or moves between differing jurisdictions (Heck and others 2004). Traditionally, this has presented few problems. In recent years however, following the commercialization of the Nile perch, its increased demand in the light of declining stock has led to conflicts or disagreements about access and control of better fishing grounds. The conflicts arise among fishers and between fishers and the enforcement authority as the authority try to control fishers cross border movements in search of better fishing grounds and markets which they do without observing the applicable fisheries and immigration regulations of respective countries.

Between 22nd – 29th April and 5th – 12th June 2002, the Project Implementation Team (PIT) of the LVFO/IUCN *Socio-economics of the Nile Perch Fishery Project Phase II* carried out a study on the nature of the conflict over transboundary fishery on Lake Victoria. The aim of the study was to have sufficient

understanding of relevant community views on fisheries management and cross border relations to be able to facilitate:

a) policy makers to address issues of conflict, authority and implementation of the law at border interfaces;
b) incorporation of community priorities into the design of management initiatives;
c) adoption of the concepts of resource ownership, management and co-management.

The study covers all border areas including islands of major fishing grounds on Lake Victoria (Figure 1). In each case, communities on both sides of the border were selected according to their proximity to the border and their significance as fishing communities. The study team carried out focus group discussions in the selected 12 communities using a standard questionnaire targeting over 500 individuals (youth, women and elders). In addition, the questionnaire was also used in personal interviews with 34 community leaders. In each district, meetings were held with 40 government officials involved in fisheries management, political leadership, or security to solicit their views on cross-border relations in their area.

The study findings and recommendations, which were discussed and adopted by the LVFO Statutory Committees and published by IUCN - The World Conservation Union and Lake Victoria Fisheries Organization (LVFO), found out that the conflict was occurring at two levels:

a) At the grassroots or local level, conflicts were emanating from among fishers as they interacted in their daily activities. Conflicts were arising from gear entanglement e.g. between long liners and drift netters, theft of nets, engines, boats and fish, use of illegal fishing gears and methods, “privatization” of fishing grounds by influential fishers through hired gangs. Participants noted that the level of insecurity in the fisheries had escalated to the point where fishers carry weapons (clubs, catapults and guns) when going fishing. Despite the conflict, the study found out that there have been very close social and commercial relations for many generations between communities living at the international border areas of Lake Victoria.

b) At the national level, conflicts were arising from fishers and the enforcement authority as the authority try to control fishers cross border movements in search of better fishing grounds and markets which they do without observing the applicable fisheries and immigration regulations of respective countries. Fishers noted that lack of customs and immigration posts on border islands in Lake Victoria has complicated their social and commercial relations with their relatives on the other side of the border. The rules and regulations of the three Partner States are not fully harmonized.

Though most fishers were (or might be) aware of the existence of these not yet fully harmonized rules and regulations, few understand their provisions. There is not only lack of uniformity between the countries in the enforcement authorities on the lake, but also fishers and local officials were also uncertain who the law enforcement authorities in these countries were, the roles and responsibilities of different institutions involved in Monitoring, Control and Surveillance (MCS) as well as the importance of MCS systems and its advantages in fisheries management. Most of the participants interviewed noted that the working relationship between fishers and authorities patrolling the lake was very poor. They mentioned cases of frequent incidents of extortion of money by patrolling agents from fishers and noted that unofficial payments had become a routine procedure for resolving cases of arrest and confiscation of property.

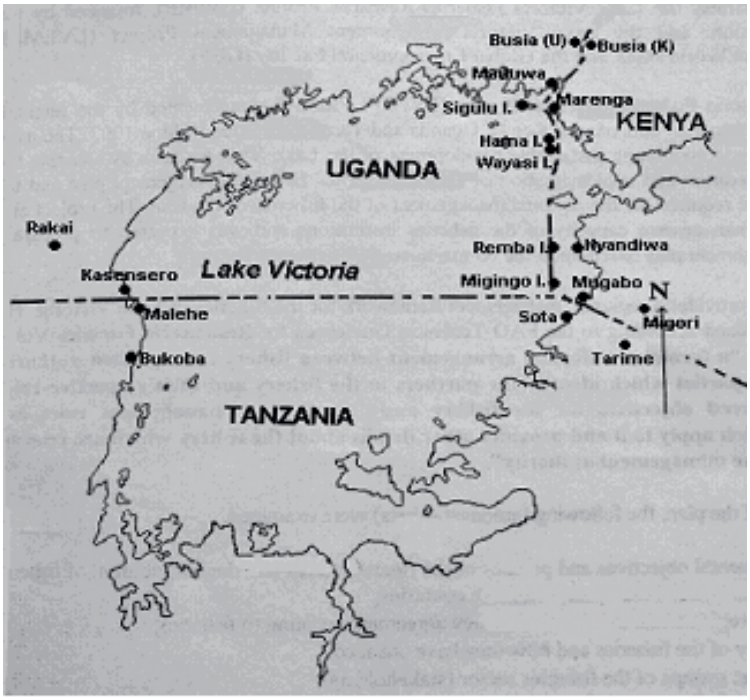

Figure 1: Map of Lake Victoria, showing study sites.

STRATEGY TO ADDRESS THE CONFLICT AND MANAGE A TRANSBOUNDARY FISHERY ON LAKE VICTORIA

Managing a transboundary resource can be seen as any process of collaboration across boundaries that increase the effectiveness of attaining natural resource management goals' (van der Linde and others 2001). It is becoming increasingly influential as a management strategy for shared resources, including fisheries. Its major components and processes are similar to natural resource management, including stakeholder involvement, identification of roles and levels within the management process, agreements committing parties to the process, and support to capacity and communication needs.

The long-term strategy to address the conflicts over transboundary fishery on Lake Victoria is to build the capacity of the cross border fisher communities to participate in transboundary fishery management and prepare Partner States for a co-management regime. The LVFO/IUCN *Socio-economics of the Nile perch project phase II* has been contributing to this process which involve the following:

Investigating the conflicts to understand their root causes, the people involved and the effects of the conflicts on communities, resources and the Partner States. The study on cross-border fishing and fish trade on Lake Victoria documented the challenges and opportunities for improved fisheries management at the international border areas on Lake Victoria.

Provision of simplified information on the legislation related to fisheries management in the three Partner States in major local languages. Most fishers are aware that fisheries legislation exists, but very few understand the provisions therein. The project produced a brochure summarizing the relevant fisheries laws in the three Partner States, and translated it into three major local languages in the lake region i.e. Dholuo, Kiswahili and Luganda. This is an important way of ensuring that fishers are well informed about the laws binding them in their country and those of their neighbours'.

Cross border exchange visits allowed the BMUs sharing common borders to meet, interact and share experiences on cross-border fishing and fish trade at all borders (Kenya-Uganda border, Kenya-Tanzania

border and Tanzania-Uganda border). These visits led to: the identification of key issues at border areas, the fostering of goodwill between the cross border BMUs to work together to resolve these issues and agreement on remedial action to address the conflicts. BMUs proposed that regular meetings be held to strengthen their collaboration.

Needs assessment proved important in identifying the needs of the communities to better participate in transboundary fishery management and appropriate interventions to address the needs. A Resource User Groups survey targeting the fisher communities was carried out and identified needs common to the border fisher communities. These included information on fisheries policies and legislation, planning, information and communication, leadership skills, financial/business management and conflict resolution. The survey report is in the process of being published by IUCN and LVFO.

Awareness raising at the levels of BMU members, district and regional fisheries officers, and national fisheries managers and decision makers proved critical in disseminating ideas about transboundary as well as co-management of the Lake Victoria fishery resources. An international workshop in October 2003 brought together BMU members, district and regional fisheries officers, and senior members of the Fisheries Research Institutes and Fisheries Departments from the 3 Partner States. Resource persons from other places such as Mekong River Commission in Asia, World Fish Centre in Bangladesh, Food and Agricultural Organization (FAO) of the United Nations (UN) in Rome, Lake Malawi and Tanga Coastal Development and Conservation Programme in Tanzania, shared their experiences about managing transboundary fishery resources with communities, managers and decision makers from Lake Victoria. This helped them to formulate a common vision for the management of Lake Victoria fishery. The workshop report has so far been published by IUCN and LVFO.

Signing Memoranda of Understanding on areas of cooperation and collaboration following the cross border exchange visits proved important to cementing cross border relations and resolving conflicts. During subsequent cross border meetings, BMUs agreed on common areas for collaboration, signed memorandum of understanding (MoUs) for collaboration and made recommendations on areas requiring direct government intervention i.e. areas beyond their control. The areas for collaboration included: sharing of information on registration of fishers and their fishing inputs, 'lost and found' fishing inputs, fish prices at the beaches, fishers arrested, and fishers using illegal gears and methods; providing letters of introduction to migrant fishers; arbitrating conflicts arising from net entanglement; assisting fishers who have drifted by wind across the border; convening regular (quarterly) cross border meetings and reviewing the MoUs after every two years.

Developing implementation plans for agreed activities in a harmonized manner is crucial in addressing transboundary issues. The BMUs, which participated in the cross border exchange visits and the signing of the MoUs together developed collaborative work plans, tailored to the specific needs of each border. Some of the activities to be implemented include: registration of fishers; registration and marking of fishing inputs; encouragement of fishers to report to local BMU official(s) in case of emergency landings due to bad weather or lack of fuel; identification of youth and other vigilant groups to assist the fisheries staff and other authorized officers in monitoring, control and surveillance (MCS); assistance to fisheries and other authorized officers in identifying law-breakers to be punished for their wrongdoing; conflict resolution arising from entangled gears; and production of legal identification cards in collaboration with the fisheries department for the BMU committees. The implementation of the work plans is to be monitored and evaluated by the District Fisheries Officers (DFOs).

Training is an essential ingredient of human capacity building, based on the needs assessed. The strategy being used is to train trainers from within the BMUs, government and non-governmental extension staff who interact with the communities on a regular basis. Subsequently, these trainers will train and disseminate information to members of their communities. The technical staffs including District Fisheries Officers (DFOs) are to supervise and/or monitor the training programme to ensure compliance to quality. The training modules include:

a) Policy, legal, institutions and institutional processes;

b) Networking among BMUs and linkages between BMUs to other stakeholders;
c) Leadership, group mobilizations and dynamics, team building and conflict resolutions; and
d) Financial aspects: Sustainable funding mechanism and financial management, collection, management and auditing of public funds (fees, levies, user utility funds etc).

Establishing a cross-border BMU network to strengthen collaboration among the communities sharing the common borders. The BMU network formalizes the partnership arrangement of fisher communities, which are organized, legalized and linked together by geographical proximity and/or common interests. The objectives of the cross-border BMU network are to:

a) Bring together cross-border BMUs in a formal management system, linking them to a regional institutional framework;
b) Improve cross-border relations and fisheries management among the fishing and fish-trading communities on Lake Victoria by promoting the acquisition and sharing of information, the culture of informed and transparent debate, negotiations and consensus building;
c) Plan, monitor, evaluate and review the implementation of the cross-border BMUs, MoUs and work plans, training programme and support BMU development and participation in fisheries management;
d) Represent the local fishing communities in regional fora related to Lake Victoria fisheries; and
e) Ensure effective networking to meet the set objectives.

Governance of the Network will include an elected committee comprised of members from the cross-border BMUs consistent with the harmonized BMU operational guidelines. Each BMU is expected to have a sub-committee on Networking. The BMU Network members are expected to organize and/or participate in at least one meeting per month within their beaches and report on the same to the District Fisheries Officers (DFOs). The two beaches sharing the common border are expected to meet at least once in three months (quarterly) funded by their respective BMUs. They are expected to report on the same meetings to the head of fisheries departments in their respective countries, through their respective DFOs. The regular cross border BMU regional network (consisting of all the cross border BMUs) meeting should take place once a year and to be organized by LVFO. Special meetings at the various levels can take place to address special and urgent issues. LVFO will plan, monitor, evaluate and provide guidance on the progress of the Network and assist in its growth and development.

The Cross border DFOs forum as well as the technical working groups established by LVFO will strengthen the BMU collaboration and networking as well as assist in the monitoring, evaluation and provide guidance to cross border BMU operations.

Outputs of the strategy

The expected outputs as a result of capacity building of the cross border fisher communities in transboundary fisheries management, as described above, are:

a) Improved capacity of the cross-border BMUs to effectively handle trans-boundary fishery management challenges;
b) Improved cross-border relations among the fishers' communities and between the fishers and law enforcement personnel;
c) Promoted culture of information acquisition and sharing, transparent debate, negotiations and consensus building;
d) Recognition by governments of BMUs as mechanisms for community participation in national and regional management processes;
e) Deepened cooperation among the EAC Partner States; and
f) The wise use of fisheries resources for improved livelihoods of the fisher communities.

CONCLUSION

Managing a transboundary resource is complex and requires a long-term strategy that entails capacity building of the resource users, a partnership arrangement between the resource users and the governments, collaboration and networking among the resource users and between them and other agencies. The LVFO/IUCN *Socio-economics of the Nile perch project phase II* provides an experience on how this process can be achieved.

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Legal and Institutional Aspects of Management of the Environment in Lake Victoria basin

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ABSTRACT

As a contribution to the environmental assessment of Lake Victoria basin this paper presents and appraises available legal provisions and the institutional mechanisms for promoting objectives of rational management of the environment. It presents the legal context of the concept of environmental and associated management concepts like conservation, preservation and the ultimate objective of sustainable development. The legal and institutional arrangements are presented, for analytical purposes only, in four categories, namely: (1) recretoral or functional statutes; (2) cross-cutting laws; (3) Framework environmental law; and (4) regional instruments. The substantive legal provisions have been discussed along with associated institutional arrangements. Although it is clear that Lake Victoria basin traverses Kenya Tanzania and Uganda, this paper is restricted to Kenya, assuming that it represents a case study from which lessons can be drawn for Tanzania and Uganda for regional harmonization of laws. The paper concludes that the most serious environmental problems in Lake Victoria Basin relate to land use especially agricultural practices; destruction of protected areas in terrestrial and aquatic ecosystems particularly to destruction of forests and depletion of fishery resources respectively; and discharge of municipal and industrial wastes which cause pollution. There are legal and institutional arrangements in the books to deal with these problems.

Key words: *environmental management, Lake Victoria basin, legal, institutional arrangements, environmental law, cross-cutting laws, regional instruments*

CONCEPTS IN ENVIRONMENTAL MANAGEMENT

For purpose of this paper “environment” is characterized as the totality of nature and natural resources as well as the composite context within which they exist and interact and includes the infrastructure constructed to support socio-economic activities and which may become part of national heritage. In other words, the specific natural resources sectors such as forestry, buildings, atmosphere/ air, land/soil, humans, fisheries, water, buildings and national monuments are simply components of environment.

Two concepts are key tools for management of environment and underscore fundamental challenges to the role of law in environmental management. The first term is preservation which means to ensure that selected components of environment such as unique biological or physical formations, endangered or threatened species, representative biomass or cultural or natural sites of importance be set aside and protected through specific legal interventions so as to maintain their characteristics in a manner unaffected by human and other activities to the fullest extent possible.

Conservation, on the other land, as a management concept, is dynamic and operational. It means to utilize renewable resources sustainably and to avoid waste of non-renewable resources. In other words, fisheries and forestry, as examples of renewable natural resources should be harvested in a manner which permits and ensures regeneration for sustainable utilization. The threshold of sustainability of use and regeneration must be protected by law, which, *inter alia,* proscribes unacceptable modes of harvesting. This is why resource economists created the phrase optimum or Maximum Sustainable Yields (MYS) and are still arguing whether the applicable term should be optimal or maximum, without denying the underlying principle. To determine the level of sustainable yield is also to determine what

should be the total allowable harvest or catch (TAC). Law should then prescribe how the total allowable catch is distributed equitably, among the registered harvesters.

The same principle applies to such resources as water or air quality. Law, indeed, does not concern itself with trivia or introduction of energy or substances which permits auto purification or biodegradability. However, law will prescribe unacceptable magnitude of change, which affects the threshold of sustainability. In other words, law does not permit use of natural resources or the environment, which satisfies the short-term interest of the present generation while jeopardizing the needs and interests of future generations. It is for this reason that the fundamental function of environmental law is to ensure sustainable development. And it is for these reasons that legal and institutional arrangements are significant for environmental management in Lake Victoria basin.

Different thematic papers have examined various sources of environmental degradation or threats to the threshold of sustainability and their environmental as well as socio-economic impacts. The purpose of this paper is to review the existing body of laws to determine the extent to which they are intended to prevent or, at the very minimum, mitigate environmental degradation. The extent of effectiveness of the laws is measured by the degree to which environmental degradation may have been stopped.

THE GEOGRAPHIC AND LEGAL SCOPE OF THE BASIN

In discussing the legal and institutional considerations the boundaries of Lake Victoria Basin are relevant from at least two perspectives, which are explained below. First, there must be a working idea of what area constitutes Lake Victoria Basin and to which any national law or treaty will apply. Secondly, the paper should describe the area of that basin under jurisdiction of Kenya and to which Kenyan environmental law applies.

Lake Victoria, like its basin, are inter-related geographic realities also recognized in law, even though some controversies have surrounded use of the term basin. History of evolution of the term “basin” is long and has involved diverse groups of scientists and legal scholars. For purposes of this discussion our point of departure is the work of International Law Association (ILA), which, at its conference at Helsinki in 1966, adopted a document proposing a legal regime for international waters including the term “basin” to apply to an area considered definite for purposes of managing the ecological unity of a lake or a river. They defined basin as that area which contributes both surface and ground water to a common terminus. The ILA’s celebrated document, known as Helsinki Rules, was given additional legitimacy when about ten years later its proposals, including definition of the term “basin” were adopted by the Asian-African Legal Consultative Committee.

There were, however some commentators or states with reservations or downright objection to the term basin and the direct meaning as in the Helsinki Rules. They argued that the definition is patently expansive and illegitimate since it may trace upper reaches of the rivers or streams and therefore interfere with the sovereign rights of a state to utilize water resources within its territory. They preferred reference to the river or lake, as such.

The long debate culminated in adoption of the term “watercourse” by International Law Commission (ILC) and forming the title of the 1997 United Nations Conventions on the Law of Non-navigational Uses of International Watercourses. A strict construction may have suggested that a watercourse is narrower than a basin and possibly limited only to the course of the river or the shores of a lake. This does not seem to be the case. Article 2 (a) of that Convention defines a “watercourse” to mean “a system of surface water and ground water constituting by virtue of their physical relationship, a unitary whole and normally flowing into a common terminus”. This definition is, arguably similar to that of “basin” in Helsinki Rules. Understandably, this definition, now adopted in a United Nations framework treaty, is expected to carry considerable influence for different bodies of water, including Lake Victoria.

One will recall that in November 1978 President Daniel Moi declared that there would be established a Lake Victoria Basin Authority to address the inequitable and unbalanced regional development in

Kenya. While some people thought there might be a political definition to the term basin to be restricted to Nyanza Province in fact, the official view was that the intention was to implement integrated and catchment-wide planning of the basin as an ecological unit. The legal definition of "basin" in Lake Basin Development Authority Act, 1979 (Cap. 442, Laws of Kenya) is coterminous with the geographical delimitation. Under section 2 of that Act the area of application of the law "means the Lake Victoria catchment area and part of Lake Kyoga catchment area situated within Kenya".

In analysing the legal and institutional arrangements applicable to Lake Victoria basin, it will be necessary to cover the entire catchment of the lake, including laws related to land use, settlements and protected areas all round the lake.

The second issue in delimitation arises from recent incidents where fishermen from Kenya have been arrested and charged with illegally fishing on Tanzania and Uganda parts of Lake Victoria. The fisherman have maintained that they were in fact arrested on the Kenya side of the border but have been convicted oftentimes when Kenya Government maintain curious silence. One of the most awkward instances occurred on Thursday, 12th February 2004 when gunshots were fired at Kenyan fishermen who had, allegedly trespassed into Hamba Island in Uganda. An exchange of gunfire between Kenyan and Uganda security forces ensued which could have resulted in an ugly incident between the two countries.

The *Saturday Nation* (p.7) reporter on February 14, 2004 summarized the situation as follows:

> **"Kenya and Uganda have had intermittent clashes over boundaries in the Lake that have seen scores of fishermen from either side languishing in jail for long periods. The question of fishing grounds remains unsolved despite several rounds of high level talks between the two countries"**

On the same page the Nyanza police boss is reported to say that "security officers would be permanently posted in the lake to counter cases of harassment of Kenyan fishermen by foreigners". Needless to say, confrontation of national security forces is certainly no way to execute sustainable management of resources of the lake.

There may be detailed nuances in the boundary over Lake Victoria, which deserve to be ascertained. We find that the description of the Lake boundary given by A.C. McEwen in 1971, in his book *International Boundaries of East Africa* (Oxford University Press p. 250) seem identical with that in First Schedule of the *Draft Bill of the Constitution of Kenya Review Commission* released on 18th September 2002.

Of course, laws on territorial boundaries, as real or dispositive instruments, are not changeable except under exceptional circumstances and by mutual agreement of the states concerned. That is why African countries accepted the doctrine of *Uti Possidetis* as a rule of practice within Organisation of African Unity (and now African Union).

The problems may be simple administrative lapses over a clearly understood boundary, in which there would be no necessity for the many high level talks referred to in the newspaper report. On the other hand if there is doubt over the precise boundary then it should be resolved. It may be necessary to have a systematic review of all legal instruments such as the 1963 Order in Council of Legal Notice No. 718 of 1963 relating to granting of independence to Kenya; Act No. 28 of 1964 on Republic status for Kenya; or Act No. 5 of 1969 and all other instruments constituting constitutional law of Kenya, to ascertain the precise boundary of Kenya over Lake Victoria. The findings should then be publicized to fishermen and armed forces which patrol the waters in order to avoid the ugly incidents.

There has been a "call to remove borders on Lake" Victoria and to institute unified management of fishing, as a solution to the frequent skirmishes and interruption of fishing by local peoples. Tanzania South member of Parliament recently said in Kisumu that "… the lake should be used as a unifying agent for the region as there are shared common concerns" (*The Standard* Supplement p. 2 November 4, 2004) In her view, the problem for the three countries should not be the boundaries but common strategies to fight pollution of the lake and to maximize economic benefits.

Whether a federation of the East African countries would obviate the necessity of boundaries will remain a moot question for a while. Creation of the European Union has not, so far, led to removal of national boundaries. What is true is that there could be unified management of the lake with common rules for conservation and preservation and a common enforcement institution. There is some challenge here for leadership on Lake Victoria Fisheries Organization, which will be discussed later.

LAWS RELATING TO ENVIRONMENTAL MANAGEMENT

Introduction

Laws that relate in one way or another, to environmental management, are numerous. In fact given the implications of the concept of environment as explained above, nearly any law can, arguably be construed to relate to environmental management. This section must perforce, be selective, confining itself to laws that affect leading areas of environmental management and affecting principal subjects of national socio-economic activity. Therefore the laws discussed are illustrative rather than exhaustive.

For convenience such laws are discussed under four broad categories namely: Sectoral or functional laws; Cross-sectoral laws; Framework environmental law; and regional instruments.

Sectoral /Functional Laws

The laws under this category are further presented according to themes of environmental management to which they relate. They are discussed under the sectoral sub-categories or functions the laws perform. Thus the following sub-categories have been identified: (a) Laws relating to land use; (b) Laws relating to protected areas; and (c) laws relating to pollution. They are discussed below in that order.

Laws relating to land use

As will have been evident from some of the thematic papers the broad area of land use presents some of the most serious problems of environmental management in Kenya. The two problematic sides are in the area of human settlement where widespread unplanned settlements lead to deplorable squalor and poor, inadequate or non-existent waste management facilities. In rural or agricultural land-poor land management practices lead to ravaging land degradation especially with extensive sheet and gulley erosion.

The important laws enacted to deal with these issues are: The Physical Planning Act, No. 6 of 1996; Agriculture Act, Chapter 318, Laws of Kenya; and Irrigation Act, Chapter 347 Laws of Kenya of which will be briefly discussed in turn. The Physical Planning Act was enacted in 1996, with the objective of ensuring the preparation and implementation of physical development and related matters. Although in practice it has been considered applicable only to urban areas, in fact the statute is intended to apply to all parts of the country. In that sense it consolidated the objectives of the Town Planning Act, which had originally been adopted in 1948 and the Land Planning Act, originally enacted in 1960, both of which were accordingly repealed by the new law.

The overall implementation of the law is the responsibility of Director of Physical Planning working with the National Physical Planning Liaison Committee comprising heads of line departments which are concerned with land use, health, education and industry, at national level. There are similar and corresponding liaison committees for Nairobi and other municipal centres as well as for each district.

At each level the officers of the Director of Agriculture are required to prepare physical development plans to advise land use especially on settlement and other environmental matters. It will be appreciated, however, that such development plans can work only where there is a clear national land use policy. It is notoriously clear that independent Kenya has never developed a land policy, let alone a land use one. Every successive National development plan since 1974 has recognized the necessity for a national land policy guided by a land commission, but has not been realized. The consequence has been the well-publicized chaos in land use, which defies any logic in a physical planning statute. The environmental

impact assessment requirement, which is laconically provided for in the Act, was never expressed in any implement regulations, and has never been implemented in any way at all. The concept will now await implementation under the framework environmental statute. In fact, it is well known that both the Town Planning Act and Land Planning Act, now repealed, were never seriously implemented.

The fact that the government never seriously intended to implement the requirements of the physical planning law has been reflected in the weak institution that Directorate of Planning has been. Observers agree that a total of 100 planners in that department, for a population of 30 million people, and the entire country is simply a token.

The Agriculture Act is the principal instrument dealing with soil conservation and agricultural land use in general. Under the Agriculture Act, the provision on "The Preservation of Soil and its Fertility" is extensive and deliberate. Part IV and XII are reserved for the subject. In the former part, the substantive provisions empower the minister responsible for lands to consult with the Central Agricultural Board to make rules (or he may direct the Director of Agriculture so to do) necessary for proper land management, cultivation and stocking.

In specific instances of improper land use practices, the Director of Agriculture may, subject to concurrence of the District Agricultural Board, issue an Order, directing a landowner or occupier to construct such works as necessary for the preservation of soil and its fertility. Under exceptional circumstances and notwithstanding any orders that may have been issued, the Minister may, if it appears to him necessary in public interest, issue an order to specific officers to enter upon private land and construct structures for the preservation of soil and its fertility. However, anyone aggrieved by the action of the Director may appeal to the Minister within 30 days. But any decision by the minister may only be reviewed by the Central Agricultural Appeals Tribunal.

Where a landowner or occupier fails to comply with the order within a specified period, the Director of Agriculture may cause entry by specified persons to carry out the remedial works or place such things, such as gabions, as may be required for the control of land degradation. Obstructing such persons constitutes an offence under the Act. On the other hand, where such entry and works are carried out the landowner or occupier is financially liable for all expenses incurred. Such decisions are, however, appealable to the Agricultural Appeals Tribunal, where such appeals do not stop the work so ordered.

The whole procedure is granted considerable prestige by the apparent independence of the Agricultural Appeals Tribunal. The Chairman of the Tribunal is appointed by the Chief Justice, from among distinguished legal practitioners of no less than seven years standing and experience on matters of land use. Members of the Tribunal must be persons with notable experience in agricultural land use. The Minister has also issued the Agricultural (Basic land Usage) Rules in 1965 which prohibits land use practices likely to enhance soil erosion. It prohibits cutting down or destroying vegetation or depasturing of livestock on any land of which the slope exceeds 35 per cent, except if the activity is done under special and express approval of an agricultural officer. Similar stringent measures are required conditions on slopes likely to lead to soil erosion.

Apart from protection of slopes under the Act, other protected areas are watercourses and riverbanks. Cultivation, destruction of soil, cutting down of vegetation or depasturing of stock on any land lying within two meters of a watercourse is prohibited. Agriculture Act, through leading to extensive land use, does provide extensive regulations to prevent, mitigate and to remedy environmental degradation, especially to prevent soil erosion. It seems evident that the institutional aspects are weak. In fact there are no known instances where Director of Agriculture has intervened to enforce the law.

There has been no known effort at all to enforce these soil conservation measures and Agriculture Act in independent Kenya, the legal provisions notwithstanding. In fact since terracing of land to prevent soil erosion during colonial Kenya were considered part of the draconian colonial policies the modern government was reluctant to pursue the measure. Recall that the problem led to establishment of the Permanent Presidential Commission on Soil Conservation and Afforestation as an administrative rather

than statutory mechanism. This, unfortunately, turned into a political rather than a seriously technical body, which has to date remained totally ineffective.

The consequence is the unabated silt loads pouring into the Lake Victoria with drastic implication particularly because Nyanza Gulf was inherently shallow but for other parts of the lake it inevitably creates hazards for navigation especially when the level of the Lake recedes for whatever reason as has been the case lately. Two Ugandan vessels, *Mv. Pamba* and *Mv. Kawa,* were reportedly stuck and could not move due to muddy and low water levels (*The Standard, December 2, 2004 p. 52*). All this presents a forceful reminder that Kenya should re-examine policy on enforcement of Agriculture Act. The primary challenge rests with the Director of Agriculture Act and the overarching supervisory role by the agency created under the Environmental Management Coordinating Act, 1999, to be discussed later. Irrigated agriculture is expected to assume increasing significance in land use in Kenya, a country with rapid population growth and high demand for food security. It is well known that two-thirds of the area of Kenya is either arid or semi-arid. Rainfall is grossly mal-distributed by season and geographical locations, necessitating national and deliberate control of water to be transferred to areas of deficit.

This task is principally entrusted to The Irrigation Act, Chapter 347, Laws of Kenya, whose commencement was 24th June 1996 to replace earlier instruments of 1966 and 1979. The central objective of the Act is to provide for the development, control and improvement of irrigation schemes and for purposes connected therewith. As a form of land use this Act clearly concerns itself with plantation type of irrigation in areas, which are designated by the Minister concerned as irrigation schemes. The Minister has powers to designate any area he deems fit, as a national irrigation scheme and this may entail compulsory acquisition of such land, and acquire title to the land.

This may well have been a source of weakness in operation of the national irrigation schemes because the farmers do not own the land. The Minister has authority to determine the number of settlers to be accommodated in national irrigation schemes. The settler/framers are therefore tenants at the will of the Minister and the National Irrigation Board, which is responsible for the development, control, and improvements (if at all) of national irrigation schemes in Kenya.

Other functions of the Board, according to the Act, include research and investigation into establishment of such schemes; to coordinate settlement on the schemes to design, construct, supervise and administer the schemes to provide land in the scheme for public purposes; to promote marketing of the produce from the schemes; to provide, where appropriate for processing of the produce therefrom; to liaise with the ministry responsible for water resources on matters related to irrigation; and to consult with the Minister responsible for finance in mobilization of financial resources for irrigation. The final and unique function of the Board is to award scholarships and bursaries to support capacity building. The overall management of the irrigation schemes is vested in the National Irrigation Board whose membership is broadly based as it includes representatives of such ministries as agriculture, health, finance and water, all working with a General Manager as the chief executive.

This law is concerned with production and marketing. Although its Boards include representatives of ministries of water and health there is no evidence of concern with water conservation and health matters. Their irrigation method is still widely based on the out-moded and wasteful furrow and sprinkler irrigation when informed irrigation worldwide was shifting to drip-irrigation. The practice in West Kano irrigation scheme pumps water from Lake Victoria and runs it through the scheme for furrow system and then releasing the drainage water back to the lake with its unmitigated load of the agricultural chemical inputs including fertilizers and pesticides. There is no obvious attention to salinization of the soil. At least such conservation measures are not reflected either in the principal act or in the subsidiary legislation.

Another factor, which may have to be changed, is the tenant-at-will approach, which means that the farmers do not own the land and therefore have no inclination to apply conservation measures. A contrast may be found between Ahero, West Kano, or Bura Irrigation Schemes, and on the other hand, Bunyala where the farmers own the land. This may reveal a difference in attitudes towards the land and its management.

Laws relating to protected areas

The representative principal statutes dealing with protected areas and which are relevant to Lake Victoria basin are the Wildlife (Conservation and Management) Act, Chapter 376; Forest Act, Chapter 385; and Fisheries Act, Chapter 378 Laws of Kenya. The Wildlife (Conservation and Management) Act (hereinafter the Wildlife Act) was first adopted in 1976 with major amendments in 1989 to change its status from a regular department, to Kenya Wildlife Service as a parastatal agency and a body corporate. The primary purpose of which is protection of wildlife. In fact, the Kenyan practice amounts to preservation in the sense explained at the beginning of this paper because cropping or sustainable utilization is not accepted for key species.

The regulatory regime adopted under the Act is that the Minister responsible for wildlife declares that a given area is a national park, national reserve or a local sanctuary. Conversely, the Minister may declare that a specific area has ceased to be so or that a boundary has been changed. A notice of establishment of such an area is issued through gazettement and interested parties may submit objections within sixty days after which the confirmed area is properly to be reported to the National Assembly for confirmation. The Minister may also demarcate an area surrounding the parts as buffer zone to promote protection of the wildlife. Fees are chargeable for entry into the park but settlement therein is prohibited.

The point of note is that apart from protection of the wildlife, such restrictions also protects forests and vegetative cover from wanton destruction and therefore protects soil from erosion. This is part of the reason why lately the government has promulgated rules for concurrent jurisdiction for forestry and wildlife protection. Recently, the Chief Conservator of Forests[20] stated that the forests and savanna are home to 40% of larger mammals, 30% of birds and 35% of butterflies. Within the Lake Victoria basin there are rather scanty areas declared for such wildlife protection. These are Maasai Mara National reserve, Ruma National Park, Ndere Island National Park, Kakamega National Reserve and Mount Elgon National Park. These are fairly old and well established. We should note that in Legal Notices No. 85 and 89 (of the year 2000) the minister issued an order declaring Lake Simbi Sanctuary and Lake Ondago Sanctuary respectively, for protection under the Act. Whether the requisite protection and development is extended to these areas by KWS remains to be ascertained.

There is some scope for management of wildlife within the basin. There is possibility of protection of wildlife outside gazetted areas, such as hippos on the shores of the lake, which have become vermins to the local peasants. They destroy crops developed through the difficult bucket irrigation by the lakeside and therefore aggravate food insecurity and poverty. In other words the law and KWS should have management strategies for wildlife, which are not confined to the parks. If the law seeks to protect the wildlife outside the enclosed parks then it must first protect the general public and their property, including crops. Otherwise the animals are not secure. Land is scanty in this area otherwise there would be a possibility of farming of wild game on private land, a practice for which incentives could be available under Environmental Management and Co-ordination Act, 1999.

To the extent that the Wildlife Act is applicable within the basin there are no obvious weakness in the law or the institutional arrangement except for the fact that the local people are to respect and protect wildlife without inverse legal protection to the human population and their property. It should be observed, though that KWS has been riddled with controversies alleging inefficiency and corruption. But these are matters of overall governance rather than existing legal regime as such.

The Forest Act, as observed above, has some conceptual and practical similarities with the Wildlife Act. It will be recalled that declaration and subsequent gazettement of areas as protected forests started shortly after the Second World War as a way of restraining the European farmers from clearing forests and vegetative cover to give way for agricultural cultivation and cattle ranching. The first Forestry Act was adopted in 1948 with subsequent piecemeal amendments upto 1992. The current opinion is unanimous that the law should be totally revamped.

20 in East African Standard April 21, 2004 p II

The current statute is the Forestry Act (Cap 385 Laws of Kenya). Initially the chief executive's had the designation of Director. Later the title changed to Chief Conservator, heading a department whose five core functions are: to manage the natural forests and protection of water catchments; to develop and manage industrial forests plantation; promotion of farm forestry; conservation and management of dry lands and forests; and development of forest policy and legislation.

Recently, the Permanent Secretary in the Ministry of Environment, Natural Resources and Wildlife reported (*East African Standard* 21 April, 2004 p.I) that gazetted forests constitute only 2.7 per cent of the total area of the country and are expected to supply wood products, non-wood products, wildlife habitats, biodiversity reservoir, carbon sinks beside soil and water conservation. As will be seen from thematic papers in this volume, this is far below the globally expected proportion of 10 per cent. That Kenya has lost its forest cover at alarming rates and through official degazettement is a matter of public knowledge. Water catchment areas have been destroyed and silt loads from bare land and agricultural fields are wreaking havoc to the Lake and destroying fish breeding sites thus threatening aquatic biodiversity.

In large measure, the problem was one of recklessness in governance and greed which makes the Post-World War II practices described above appear mild and discrete. In the pages referred to above the Permanent Secretary submits rather resignedly that there is no "quick fix" to the crisis facing sustainable resources management in Kenya. She adds though, that the government had "embarked on institutional, policy and legal reforms that are expected to transform Forest Department into an efficient service and regulatory agency".

As far as can be ascertained a draft Forest Policy has been prepared. In addition a Forests Bill, 2004, widely regarded as well-conceived was presented to Parliament in May 2004 but rejected by the majority on account of diverse political and technical arguments. These differences should be resolved so that the bill can be re-introduced for possible enactment. Political arguments in matters of this sort are often short-lived. The major technical argument to be considered in the bill is the status of the so-called *Shamba System, which allows local communities to farm in the forest,* and thus attend the seedlings. This remains controversial as opponents argue that the practice is easily abused.

Other issues being considered at policy and legislative levels is regulation of charcoal burning as well as production and marketing of the product. This is tied to illegal harvesting of trees, charcoal making and wildlife hunting in forests. These elements cannot be fully addressed without another issue on the agenda, namely integrating local communities and other stakeholders in conservation and management of the country's forests. It is expected that the severity of penalties attending violation of forestry law will be properly reviewed.

In our view the most fundamental of all juridical issues in management of forests is that of degazettement of forest in favour of settlement and agriculture. Its solution lies in the question of ownership of the country's natural resources. Whenever it is assumed that the government is the owner and custodian of the natural resources including forests, the respective government officials assume the role of private property owner. This is the paradigm, which has, fallaciously in our view, led to degazettement and allocation of forestlands to private individuals by the government. A proper legal regime should vest the natural resources in the people of Kenya and assign the trusteeship role in Parliament. All degazettement, concessions or contract leading to alteration of boundaries or exploitation of the natural resources would require two-thirds parliamentary majority approval. It is only that kind of drastic and fundamental change in the legal regime, which offers restraint, and protection of the limited forest land left.

To date, there have been frequent degazettements of forest land. Hardly does one see instances of fresh gazettements. Kenya's Land Acquisition Act (Cap. 295) permits the government to acquire land compulsorily for public purposes, including for conservation purposes. It is conceivable that the government could compulsorily acquire or repossess forest land, which had been alienated to restore them to their conservation roles. This can be done without a constitutional dispensation required for natural resources ownership. The present instance depends on political will to implement an existing legal provision.

The Fisheries Act (Cap 378) is unique in the subset of protected areas. There are, indeed, protected areas for fisheries where breeding areas or ecological zones become protected with or without seasonal specifications. Nevertheless, fisheries as a natural resource sector is inherently protected in the lake or rivers to ensure maximum (or optimum) sustainable yield. There is a necessity for regular surveys to determine the distribution and abundance of specific and general species. The result enables the regulatory agency to determine the total allowable catch by species or ecological areas and by what years. By the same token the regulatory agency must determine the safety standards for fish generally and then draw up and support the requisite universal and undifferentiated *codex alimentaris* to be enforced. The Fisheries Act is, therefore, concerned with both qualitative and quantitative aspects of fisheries management.

The date of commencement of the current Act was 25th August 1989 but it underwent significant revisions in 1991. According to the long title the general-purpose of the Act is to provide for the development, management, exploitation and conservation of fisheries and for purposes connected thereto. The development measures are further elaborated to include extension and training services; research and surveys; promoting cooperation among fishermen; arrangements for orderly marketing of fish; providing infrastructure facilities; and stocking waters with fish and supplying fish for stocking. On the other hand management measures are specified to be to impose one or a combination of such measures as closed seasons for designated areas, species of fish or methods of fishing; prohibited fishing areas for all or designated species or methods of fishing; limitation on methods of gear, including mesh sizes of nets; limitation on amounts, size, age and other characteristics or species of fish; regulate the landing of fish and provide for the management of fish landing areas; and control of the introduction into or harvesting or removal of any aquatic plant in any Kenya fishery waters. We note that nothing in either development or management is said about maintenance of quality.

The Chief Executive in Department of Fisheries is Director of Fisheries who has power to implement the conditions for management or development. The director may exercise the relevant administrative duties directly or through such fisheries officers as may be specifically authorised so to do. In addition the director may work in conjunction with appropriate agencies or government departments to promote development in the fisheries sector. As tools for management, the Director registers and issues licences in respect of fishing vessels and may therein specify the species and quantities of fish permitted or specific areas where the fishing license applies. The conditions apply to local or foreign fishermen and vehicles. Licences for fishing in Kenyan fishery waters are applicable to Lake Victoria since uniform regulations for the three East African countries have not been developed.

In general the, most important mechanism for management and promoting sustainability in the fisheries sector are: limitation on gears that may be used, including mesh size of nets, that may be used; limitation on the amount, size, age; and composition of species which may be caught landed or traded; regulation on landing of fish and management of landing areas; and introduction into or removal of any aquatic plant. Further, the Director also has powers to designate areas as closed for fishing of given species or methods of fishing.

One of the little known regulations is that a license is required to trade in fish. In the Fisheries (general) regulation issued as Legal Notice 34 of 1991 the law specifies that no one may trade in fish except if the person is properly licensed as a fish trader a licensed fisherman; a fish farmer; or a fisherman's cooperative society. Trading in violation of these provisions constitutes an offence punishable by a fine of upto twenty thousand shillings and/or imprisonment for one year.

The regulations generally prohibit trawling as a method of fishing within five nautical miles from any point on the entire shoreline of Kenya waters of Lake Victoria. But trawling within Nyanza Gulf is entirely prohibited. Similarly, a fisherman may only use seining net whose mesh sizes are less than 50 millimetres when diagonally stretched only for *Rastrineobola or Omena.* However seining for *omena* with nets whose mesh sizes are less than 10 millimetres is prohibited. There are also prohibitions against catching or landing fish caught with illegal gears. The rationale for all these provisions is to prevent catching of juveniles of the species and therefore threatening the threshold of sustainability. Also protected are the

anadromous and catadromous fish species such as *ningu* in the river systems or within three kilometres radius of the delta or estuary of any river during breeding seasons as may be declared by the Director in official gazette.

Generally, the trawl fishermen scoffed at the meagre fines and/or imprisonment prescribed on the regulations for Lake Victoria. A new Legal Notice No. 18 was issued on 18th January 2001, to authorize the Director of Fisheries or any authorized officer to seize and detain trawlers or trawl nets. On conviction the trawlers or trawl nets are automatically and mandatorily forfeited to the Government and are ordinarily destroyed.

The regulations treat measures which render the fishing environment and navigation hazardous on the same plane of seriousness as all Kenyan fishery waters are declared "pollution prevention zone". In other words, the law prohibits negligently or intentionally placing, discharging or abandoning any fishing gear or pollutant which may cause harm to fishery resources; interfere with fishing or obstruct fishing gear or vessel or become hazards to navigation. Anyone who notices the discharge of pollutant or abandoned facilities is under obligation to report to Director of fisheries specifying the items noticed and the co-ordinates.

It may be argued that by the regulations applying only to intentional and negligent placement or discharge it waters down the requirement, especially for polluting acts which introduces hazardous substances into the water. Strict liability rule may be necessary under the circumstances in order to promote proper level of diligence for all operators in Kenya's fishery waters. This may, however, be covered by the polluter-pays principle in National Environment Management and Coordination Act, 1999 which will be discussed later. It is sufficient to mention at this point that the regulations prescribe a fine of a mere twenty thousand shillings and/or two years imprisonment on violators of the pollution and safety provision.

General provisions on pollution have, however, proved woefully inadequate for fish quality assurance especially in export market where the economic impacts at national levels are at stake. It became increasingly essential to create institutional mechanisms to, *inter alia,* monitor fishing grounds, fish landing grounds and to provide health certification for fish and fishery products. The minister promulgated Legal notice No. 100 entitled The Fisheries (Fish Quality Assurance) Regulations, on 11th August 2000, which designated an Authority comprising the Permanent Secretary, Director of Fisheries and Director of Veterinary Services to ensure the above functions.

Despite the foregoing plethora of legislative development, public information is still awash with reports that fish stocks in Lake Victoria, particularly Nyanza gulf, are getting gravely depleted and pollution from urban, industrial and agricultural centres is largely unabated. It seems that the problem lies entirely with enforcement (*The Standard, November 25, 2004 pp. 2 & 3)*. As far as quantitative management is concerned, it may be necessary to complement the rule and punishment regimes with promotion of compliance and fishermen's self regulation through beach management units. On the other hand prevention of pollution will require broadly based action under the Environment Management and Coordination Act, 1999 and extraordinary measures of restoration of catchments destroyed through deforestation.

On a broader scheme it may be appropriate arranging for an East African Community level of legislation and enforcement. Initial framework may already exist in the Jinja-based East Africa Fisheries Organisation which will be discussed later in this essay.

Law relating to pollution control

The single most worrisome environmental problem in Lake Victoria and its entire catchment is pollution from various sources all of which have been fully discussed in the thematic papers. It was clear for instance in discussion of fisheries law that pollution is a central concern. It is noted though that in the fisheries legislation, pollution is discussed as an end-of –the-pipe matter. In other words pollution, or

actual discharge of substances or energy in a manner likely to cause deleterious effects or impairment of amenities is prohibited.

This section now examines the legal provisions controlling pollution at its source; one such source is agricultural fields constituting a source of pollutants in the form of silt-load containing agricultural inputs. This falls in the category land use, which has been discussed already. The present category will be limited to pollution from domestic or municipal sources and pollution from factories. Among the laws relevant to this category are Public Health Act, Cap 242; Factories Act, Cap 514; and the Mining Act, Cap 306; and Water Act, 2002.

The Public Health Act has several provisions which prohibit pollution of water and air, both of which may result in degradation of Lake Victoria Basin. In the Public Health Act, these fall under the broad range of provisions under the rubric of prevention of nuisance; they are also covered under control of discharge of waste, wastewater or other noxious matter into any body of water or in the air. It is an offence to make such discharges. A medical officer of health who is satisfied that such an offence is being committed may serve notice on the author of the nuisance and demand cessation of the activities. Failure to comply with such directions constitutes an offence.

Remedies are available, though. Whenever a medical officer is satisfied that the nuisance, even if removed, may recur, he may request a court of law for an injunction against the perpetrator of the offence. At its discretion, the court may direct that specified works be constructed to ensure permanent solution and, in the extreme instances, and injunction may be issued to direct that the operation responsible for the discharges, be stopped until corrective works are in place and operational.

It should be observed that additional provisions are available under the Public Health (Drainage and latrine) Rules to prohibit the disposal of sewerage, which may, *inter alia,* endanger the purity of any water or create nuisance. The companion statute to Public Health Act is the Factories Act whose original principal objective is operation of factories and protection of workers. However, the statute underwent substantial substantive amendments by Act No. 1 of 1990. Among the several new provisions is the requirement under the section on “health, safety and welfare” which prohibits the emission of dust, fumes, exhaust gases or other impurities from being released into environment without sufficient treatment to prevent pollution or other deleterious effects on life and property.

The statute empowers the minister responsible for labour to promulgate additional general or specific rules to regulate discharges of pollutants from factories. Authorized officers or factory inspectors may enter a factory to ascertain compliance with the law. In the course of such inspections the authorized officer may collect samples of any substances, for analysis by the Government Chemist, and which can be used in criminal prosecutions against the factory in case the analysis confirms violation of the law.

It is common knowledge that the Public Health and Factories statutes are some of the most blatantly violated laws in Kenya. It has become “normal” that municipal and industrial wastes are released into waterways and in the atmosphere absolutely without any restraints. Nearly all such discharges within the basin end up in Lake Victoria. It can hardly be argued that there is lack of law or institutional machineries. As noted from above, these are abundant. What is evident though is the well-known failure of the Attorney General to intervene on behalf of the public, to ensure cession of the gruesome pollution lightly referred to in law as nuisance. Although the requirements for action by medical officers are expressed in mandatory terms, members of the public have not moved to seek enforcement using available legal remedies to seek enforcement against public nuisance because of the technicalities and uncertainty associated with such forms of actions.

There is now growing awareness of the options available under the Environmental Management and Co-ordination Act, 1999, as a framework law to be discussed later in this paper. The Mining Act deals principally with arrangements for contracts and concessions for exploration and extraction of mineral resources. No provisions are made specifically to avoid wastes of the non-renewable resources. The lessee is however required to prevent any form of nuisance to neighbouring premises or property. The law requires that

compensation be paid for interfering with other adjoining activities. In addition, the lessee is prohibited from releasing any poisonous substance into waterways. On abandoning the mining operations, the lessee is required to rehabilitate the site to prevent any person of animal from entering the dangerous terrain.

Water, as a sector, is arguably, the most pervasive, in terms of sectoral conservation and management of environment. The very concept of Lake Victoria basin is defined in terms of water and hydrological behaviour. Both qualitative degradation and quantitative use affect viability and sustainability of the environment of Lake Basin. Therefore, the sectoral statute on water will receive a larger and more detailed discussion than the other sectoral laws.

The process to develop and update the water statute to replace the Water Act, Cap. 372 started in 1970's. The Government finally completed the National Policy on Water Resources Management and Development, which was adopted as Sessional Paper No. 1 of 1999. Out of that process The Water Act, 2002 was adopted by Parliament as Act No. 8 of 2002 which received Presidential Assent on 17th October 2002 making it one of the most up to date environment-related statutes in the country. It is also true that it was enacted after considerable national debate. Therefore, expectations on its suitability to address relevant issues is very high.

The principal objective of the law as expressed in its long title is that it is: "An Act of Parliament to provide for management conservation, use and control of water resources and for acquisition and regulation of rights to use water; to provide for regulation and management of water supply and sewerage services; to repeal the Water Act (CAP 372) and certain provisions of the Local Government Act and for related purposes". There are several institutions created under the Act with particular details reserved for water services, especially in municipal areas on a broader scale. Nationally the principal institutions which were declared operational by Gazette Notice No. 10340 of 31st December 2004 are five, namely:

(1) Water Resources Management Authority (WRMA) with the core responsibilities of implementation of the policies and strategies for management of water resources. The Authority is also responsible for catchment level management strategies; most of the macro-level management will be by delineated catchments. Lake Victoria Basin, for instance will be divided into two catchments: South and North.
(2) Water Services Regulatory Boards will be responsible for overseeing the implementation of policies and strategies relating to provision of water and sanitation services (WSS). They will also regulate the provision of WSS, licensing of Water Services Board (WSB's) and approving the appointment of Water Service Providers (WSP's). For a long time these will operate largely in municipalities;
(3) Water Services Board (WSB) will be responsible for the efficient and economical provision of water services. They are also the asset holders of central government facilities.
(4) Water Services Trust Fund (WSTS) which will assist in seeking and mobilizing financial resources for provision of water supplies in areas inadequately provided for.
(5) Water Appeals Board (WAB) will be responsible for settlement of disputes and resolution of conflicts.

For purposes of this study the principal focus is on the Water Resources Management Authority, or broad issues of management, conservation and control as they relate to catchment areas. Earlier in this paper we received the explanation that Lake Victoria Basin on the whole has the totality of its overall catchment. But to satisfy the requirements of water management strategy the Water Act too, has designated "catchment areas" for the whole country so that each drainage basin has its catchment and sub-catchment areas. Although the gazettement has not been done at the time of this study it is confirmed that the Lake Basin has been divided, legally, into two catchments: Lake Victoria North and Lake Victoria South; A management strategy is then to be drawn by the Water Resources Management Authority with the guidance of a 15-member Catchment Area Advisory Committee to be composed of people who are conversant with the subject and geographical area. The Advisory Committee is expected to maintain a regular review of the catchment to be able to advise on water resources conservation, use and apportionment; the grant adjustment, cancellation or variation of any permits; and any other matter pertinent to proper management of water resources.

Programmes for utilization of the water resources must be prudent. Circumstances may arise where specific parts of the catchment area require special protection. The Authority, on appropriate advice may, by gazettement, declare an area to be a "protected area" and impose requirements and regulate or prohibit certain conduct or activities as may be deemed to proper conservation practices. It is conceivable, therefore, that the Authority can impose exemplary conservation measures of protection such as deforestation or farming practices in Mau, Cherengany or other forest areas if they are deemed to threaten the property husbandry of water catchment.

To facilitate rational conservation strategies the statute provides for mandatory establishment of a national system for monitoring and information on water resources management. Such a system shall provide for collection and management of data and information, including procedure for gathering, analysis and dissemination of information. Any person may be required to provide relevant information or data, which may be in his custody. But such a catchment specific system of information may, for different purposes, be linked to the corresponding national monitoring and information on water services.

In the foregoing scheme it has been indicated that there will be private projects for which permits may be issued. Similarly, there may be state schemes for public purposes, especially those for supply of water or hydroelectricity; reclamation of lands; protection of any water resource or its catchment; improvement of water quality; flood control; or impoundment for purposes of bulk distribution. The law provides that such schemes will ordinarily take precedence over all other schemes, with only a few exceptions granted by the Minister.

The primacy of the community or state schemes is further underscored by the provision permitting the minister to acquire, in any manner, including compulsorily, any land required for such schemes. Provisions are also made for possible leasing of such land, if that is preferable to outright acquisition. In each case, however, it is expected that an appropriate compensation shall be paid. But the law is also unequivocal that use of water for domestic purposes takes precedence over use of water for any other purpose. In granting any permit the Authority is required to set aside quantities of water necessary for domestic purposes.

For purposes of environmental conservation it imports that the public projects discussed above may include protection of any water resources, its source or catchment, control and management of floodwater; and conservation or improvement of water quality. For lake Victoria Basin, these are extremely important environmental provisions, which the Minister would be expected to implement right away.

The qualitative aspects of water are provided for in one concise and unequivocal section of the statute. Apart from prohibiting obstruction, diversion or abstraction of water without permit, the law makes it an offence to introduce into a watercourse, any rubbish, dirt, refuse, effluent, trade waste or any other material which causes or are likely to cause pollution. The general penalty for offences under the Act is a fine not exceeding one hundred thousand shillings and/or a prison term of twelve months. It may be argued that for a statute, which is only two years old, and at a time of both water scarcity and rapidly increasing demand, the maximum sentence is woefully lenient.

This discussion has focused on provisions of the statute, which are environmental. What is clear is that the statute is reasonably generous on matters of conservation and management of water resources and thus making it a sound focus for environmental management in the basin. One important observation is that the Water Act standing alone is still on precarious grounds unless other laws, particularly on agriculture, forestry and public health are strong and get enforced. The issue of even enforcement of existing laws is critical and depends on effective implementation of a framework statute, to which we shall turn later.

Crosscutting Laws

By crosscutting laws we refer to statutes that are not limited to one sectoral subject. The one prominent subject used as an example of a statute of environmental significance, is a law creating a regional development authority, or the *Lake Basin Development Authority Act*, Chapter 442 Laws of Kenya.

The idea of this regional development authority was a political announcement in November 1978 by President Moi during the first visit by a national president to Kisumu in a decade. It was to be a response to what was considered a politically motivated neglect of the area's development needs by the government and therefore a statutory approach to mobilization of natural resources within the basin and to intensify development initiatives beyond what the line ministries were doing. The idea was an expanded vision of what Tennessee Valley Authority had done in United States in 1930's. In the legislative context the purpose of the statute, as expressed in the long title was "An Act of Parliament to provide for establishment of an authority to plan and coordinate the implementation of development projects in the Lake Victoria catchment area and for matters connected therewith and incidental thereto". It was adopted within a few months after the political statement; the date of commence was 31st August 1979. The area of application of the law is specified as "The Lake Victoria catchment area and that part of Lake Kyoga catchment situated within Kenya". Physically, that means Nyanza and Western Provinces, as well as parts of the Rift valley particularly in Uasin Gishu, Kericho and Narok districts. In other words the area of jurisdiction of the authority is coterminous with the area of Lake Victoria catchment under this study.

The institutional framework for implementation of responsibilities under the Act is a unitary Lake Basin Development Authority (LBDA) as a parastatal organisation and a body corporate whose chief executive is a managing director working under an Authority as a governing board. Members of the Authority include permanent secretaries in finance, parent ministry and agriculture, with the Director of Water Development. It also includes provincial commissioners for Nyanza, Rift Valley and Western provinces to underscore the significance of geographical coverage. Independent members appointed in personal capacity are twelve, of whom nine must be residents of the catchment area.

The functions of the Authority are focused on planning and execution of projects, specifically those related to natural resources, particularly agriculture, forestry, wildlife, tourism, electric power, mining and fishing. Besides, the authority has the responsibility to examine hydrological and ecological effects of development programmes and to determine ways of ameliorating adverse tendencies. One of the novel assignments of LBDA is to monitor operations and to issue reports on any aspects of existing treaties on utilization of waters of Lake Victoria and River Nile.

As will be evident, the functions of the Authority are primarily planning, coordination and execution of projects. It has no enforcement powers. During its early years the Authority used the mandate to organize a regional workshop on water quality in the basin, bringing together participants from Kenya, Tanzania, Uganda, Rwanda and Burundi with participants from U.S., in August 1982. This was repeated in 1985 but nothing followed. The Authority conducted extensive studies on the waters of the basin, including the UNDP funded hydrological analysis intended for flood control, irrigation and hydropower generation, which was completed in 1986. Very little else followed after that. A victim of problems of poor governance in 1980's and 1990's the Authority can be described now as being only politically alive. Functionally its life is doubtful. It should, indeed, be made to work given appropriate leadership and governance.

FRAMEWORK ENVIRONMENTAL LAW

The need for what are today known as framework or umbrella environmental laws became evident in western countries because of the manifest failure of the regime of sectoral or function specific statutes such as those described so far in this study. Sectoral or function specific urgencies fail to carry out their administrative and enforcement powers. At the same time the attorney- general, as the public prosecutor, fails to intervene to enforce state police powers. Members of the public, as individuals, have no powers under the statutes to take enforcement measures to protect the environment. Their mandates under the regime of common law were restricted to seeking judicial enforcement against injuries to personal or proprietary interest. Moreover, there were no requirements for measures to ensure prudence and precaution against measures that may cause deleterious effect and therefore to ensure that mitigating measures are taken to protect the threshold of sustainability in utilization of environmental resources.

That was also the situation in Kenya until December 1999 enactment of The Environmental Management and Co-ordination Act, 1999 (as Act No. 8 1999), which received Presidential Assent on 6th January

2000 and designated for commencement on 14th January 2000, signalling that the government wanted to see its immediate implementation of a law now applying to the whole of Kenya, including the basin. The first important point to note is that enactment of framework environmental law does not, in any way whatsoever, obviate the significance of the specific sectoral or functional law and their enforcement roles. Quite the contrary. The sectoral statutes are expected to be enforced by the lead experts with the primary responsibility for both productivity and development on the one hand, and on the other hand, the responsibility for ensuring a sustainable environment. Therefore, the specific sectoral or functional statutes are expected to be reviewed and brought into total harmony with the framework law. Section 148 of the Act provides that:

"Any written law, in force immediately before coming into force of this Act, relating to the management of the environment shall have effect subject to modifications as may be necessary to give effect to this Act, and where the provisions of such law conflict with any provisions of this Act, the provisions of this Act shall prevail",

This section alone shows the enormous authority and confidence which Kenyan legislators vested in the framework statute; the institutions established under the law, with their functions; and other substantive issues governed by the law. It will therefore be useful to take a quick tour through the above issues. The central organ established under the Act is the National Environment Management Authority (NEMA) with a Director-General as the chief executive. NEMA is a parastatal agency and a body corporate with the generic legal competence of all such bodies in Kenya. During public debates to build consensus on the evolving the bill Kenyans placed considerable emphasis on the title "director-general" to emphasize that in this Act, the functions of that office would be above that of other departmental directors.

The functions and objects of NEMA, to be executed by the Director-General are both administrative and environmental. The central and regular function is to co-ordinate various environmental management functions undertaken by the line departments, or organs referred to as lead agencies to ensure rational management for sustainable development. A central place is given among the functions to land use where the Authority is required to take stock of land and natural resources, conduct consultations with lead agencies with mandates in land use matters and to provide national land use guidelines.

Twin functions to the above include initiating and coordinating research and surveys and monitoring with a view to developing strategies for prevention of environmental management and standards and procedures for mitigation of degradation. To prevent conflicts and duplication of initiatives and encourage synergies among departmental environmental efforts, the Authority is to initiate and encourage complementarity and cooperation as well as broad based public education. Within these initiatives the Authority is required to identify issues which require either legislative action, promulgation of new regulations or implementation of treaties and advise the government. Similarly the authority is required to assess regional and global environment treaties and advise the government on the circumstances when Kenya should be party to the agreements. There are a number of studies and reports, which the Authority is required to issue periodically. Among these, an annual report on the state of environment is to be submitted to parliament annually and this is mandatory. Other specific responsibilities of the Director-General on matters of environmental planning and management will be explained later below.

It is important to point out that the Authority works under a board of directors as the policy-making organ. The law requires that the Minister must appoint members who are highly literate environmentally and representing a broad cross-section of stakeholders in the field. Above the Board of Directors is the little known National Environment Council chaired by the Minister himself and comprising permanent secretaries in Ministries concerned with environment, all identified in the Act (in form of First Schedule). Others are from universities, research institutions, industry and non-governmental organizations. The idea was that the task to be accomplished by the Authority is onerous and may at times require support at a more senior level. It is a forum for political legitimation of the work of the Authority much like the Council of Environmental Quality, which is located in the White House to back the responsibilities of Environmental Protection Agency in the United States.

There is one organ under the framework law which is rarely mentioned and possibly often ignored but which has a central role in the Act. It is the Standards and Enforcement Review Committee established under Section 70, to bring together heads of all lead agencies identified under the Third Schedule. The role of the Committee is to keep standards and enforcement procedures under review and to recommend ways of promoting effectiveness of the law. Essentially, this committee is to avoid alienation of any line agency; instead it keeps the stakes of each agency in constant focus. It is chaired by the Permanent Secretary so that the Director General is left to play his diplomacy and negotiation to ensure that national environmental objectives are respected.

Since the Authority is a national institution with mandate down to locals levels the Director-General has a representative at the provincial and district levels working under policy direction of a Provincial and District Environment Committee, respectively. A broad avenue of public participation is opened by establishment of a Public Complaints Committee, which can freely investigate any complaint and urge for action by the Authority. Anybody can complain directly to this Committee; at the same time the Committee can take up a problem from any source including the press. It submits its periodic reports to the Council and not the Authority since at times investigations may challenge performance of the Authority. Therefore, environmental degradation in the Lake Basin, which are not acted upon by the line department and the Authority may be reported by way of a complaint to this Committee.

The Authority is required, mandatorily, to undertake environmental planning in preparing a National Environmental Action Plan (NEAP) every five years. This is to be preceded by a Provincial and District Environmental Action, respectively, every five years so that the NEAP is a reflection of the district and environmental efforts. The NEAP will also propose issues requiring legislative action. Consequently, under the framework law, no issue of grave environmental concern in Lake Victoria Basin should remain unattended for longer than five years, as is currently the case. The requirement for exercise of prudence and precaution, which is fundamental to protection of environmental sustainability, is the centrepiece of the framework statute. It is expressed as the well-known rule of environmental impact assessment (EIA) whereby studies are required to be done by proponents of all projects likely to have significant effect on environment. Such studies are required to show any probable deleterious effects and how an implementation of the project such effects will be satisfactorily mitigated. There is a list in the Second Schedule to the statute, showing the kinds of projects for which EIA is required. It is detailed and all-encompassing. The process of reviewing such a study requires that it be open to participation of all interested people and stakeholders. For that reason, it is a statutory requirement that the study be made available to all such stakeholders for review. Frequently, NEMA has placed announcements in newspapers inviting interested persons to review the study.

Only projects, which pass this test, may be licensed by NEMA to proceed. Anyone not satisfied by a decision taken in this administrative process may seek redress before a National Environment Tribunal, a flexible non-judicial and independent body established under the Act. Decisions by the Tribunal may be appealed before the High Court, whose jurisdiction is original and unlimited.

The statute lists a broad array of environmental areas that require special protection and conservation measure. The list includes matters that are critical within the Lake Victoria Basin. They include protections of rivers, lakes and wetlands; hill tops, hill sides, mountains areas and forest; conservation of energy; conservation of biological diversity; access to genetic resources of Kenya; environmentally significant areas; coastal zone; and ozone layer. The law also makes provision for use of economic incentives to induce compliance with environmental standards. All activities to be undertaken within the Lake Victoria Basin are subject to these important regulations and procedures.

Ongoing projects and activities are subject to environmental audit, in the same sense accounting books are audited, to ensure that the rules, procedures and standards are adhered to and to identity where improvements are essential. Operating licenses may be withdrawn and steps to seek penal sanctions and environmental restoration may be sought.

This is why the statute provides also for environmental quality standards to be adhered to. The statute sets out conditions and standards relating to water pollution and prohibition effluent to be discharged into

sewerage system; air quality standards; specially vulnerable and controlled areas; vehicular emission; handling and disposals of dangerous wastes; toxic and hazardous wastes, chemicals and materials; pesticides, noise; ionizing and other forms of radiation; and noxious smells. Where environmental standards have been breached the Authority may issue an environmental restoration order requiring the perpetrator to take specified measures. It has been argued that actual restoration may be impossible to achieve in some cases. If "restoration order" is found to be a misnomer then the Authority as well as the public may be satisfied with what amounts to rehabilitation of the environment.

Under special circumstances an individual a group of people or NEMA may apply to High Court for issue of an environmental or conservation easement with respect to a specified land. The order may apply to the burdened land for a term or years of perpetuity. The object and functions of the easement should be clear but may be to preserve flora and fauna, a scenic view or open space; preserve the quality and flow of water in a dam, lake, river or aquifer; to preserve any outstanding geological; ecological physiographical; archeological; or other historical features of a burdened land; permit persons to walk in a defined path across a burdened land; preserve contours and features of a burdened land; prevent or restrict the scope of any activity on the burdened land which has its object the mining and working of minerals or aggregates; restrict or prevent the scope of an agricultural activity; or create or maintain a migration corridor for wildlife. In each case such an environmental easement issued on a court order shall be registered by the District Environment Committee of the area where it is applicable. The court issuing the order will also determine the quantum of compensation to be paid and whoever is responsible for payment.

The Act authorizes NEMA to employ inspectors whose duty it is monitor and ensure compliance with the requirements. An inspector may, at any reasonable times, enter any premises or vessels and without warrant to inspect records; take samples, seize any articles, vessels; vehicles or equipment which may constitute evidence in court proceedings. With a written approval of the Director General, inspectors may order an immediate closure of a plant or other establishment which are in breach of environmental requirements under the Act. With an arrest warrant an inspector may, with assistance of a police officer, arrest anyone reasonably suspected to have committed an offence under the Act.

Enforcement powers under aegis of the Authority is a well-known practice in administrative law. The novel provision in this statute is that it grants *locus standi* (or the right to sue before court of law) to individuals to seek court orders protecting environment without demonstrating personal interests. Section 3(1) provides that any person in Kenya, not restricted to citizens, is entitled to a clean and healthy environment and has the duty to safeguard and enhance the environment. Thereafter, paragraph (3) the person referred in paragraph (1) may apply to High Court for redress and the Court may issue such writ or give direction it deems necessary to correct the wrong being committed. Under paragraph (4) the Act says that that the person bringing the action does not need to show that that action by the defendant causes him any personal loss or injury.

Clearly, there is no reasonable ground for continued environmental degradation in Lake Victoria Basin where action is not taken by line departments, NEMA or civil society organizations or individuals. Necessary legal and institutional arrangements are provided under this statute and they cover planning, management and enforcement. Where the standard public institutions fail to act, individuals can use judicial mechanisms to seek redress. The law also provides principles to guide the High Court in deciding an application for redress for environmental degradation. The five principles stipulated under the Act are: public participation in the development of policies and management of environment; respect for cultural and social values traditionally applied by local communities; principle of international cooperation (as would be applicable in Lake Victoria Basin); inter-and intergenerational equity; polluter pays principle; and the precautionary principle. Clearly the statute is as modern as one can expect, incorporating some of the latest principle in environmental law to back up a comprehensive system of planning management and enforcement.

REGIONAL INSTRUMENTS

Introduction

The principal regional instrument on regional cooperation, which is applicable to Lake Victoria Basin today, is the Treaty for the Establishment of East African Community, which was adopted by Kenya, Tanzania and Uganda on 30th November 1999. But this is certainly not the first such framework of regional cooperation for the three countries. The initiatives started with the East African Common Services Organization, a colonial creature, in 1948. As the title implies it was the legal framework within which colonial Britain organized certain common services in Kenya Colony, Tanganyika Trust Territory and Uganda Protectorate, and Zanzibar, which was also a protectorate.

After the end of colonialism, independent Kenya, Uganda and the Untied Republic of Tanzania agreed and signed the Treaty for East African Cooperation at Kampala on 6th June 1967. The agreement went into force on 1st December 1967. By and large, its focus was trade and services. It had practically no provision of direct environmental concern. The significance in the modern sense and the parties had no pretensions on environmental concern. The closest they reached to environment were studies conducted by the Community's institutions such as the East African Medical Research Institute, where Dr. Eyakuze, one of the researchers, warned in 1971 that pollution of Lake Victoria was increasing dangerously and that if measures to arrest the trend were not taken then the lake water quality faces a grave future.

Such warnings were simply ignored: there was neither legal provisions nor institutional machinery to guide collective response of the three countries. In any event, that collaborative framework ended with the acrimonious collapse of East African Cooperation and the termination of the treaty in 1977. Nearly two decades later, the atmosphere of hostility and acrimony had faded away and the search for a new collaborative framework was nurtured. This resulted in mutual agreement and the signing of the 1999 Treaty. What will be definite too is the preoccupation in the treaty with issues in environment, natural resources management and sustainable development.

The Framework Treaty

The Treaty for the Establishment of the East African Community is characterized as a "framework treaty" because its provisions anticipated a number of instruments, such as protocols focusing on specific issues. As a treaty, this instrument is not self-executing. Its adoption by signatures of the three heads of State and Governments left it subject to ratification before it could enter into force. Beyond that and certainly more important the treaty was subject to domestication by each of the Partner states and through that process, each country's enabling statute would appoint the date on which it takes effect in their respective countries.

Kenya domesticated the agreement into national law through the enactment of the Treaty for the Establishment of the East African Community Act, 2002, which received Presidential Assent on 11th July 2000. By legal Notice No. 137 the Minister appointed 29th December 2004 as the date on which the Act, and therefore the treaty, came into operation in Kenya.

The treaty has five articles that are of environmental significance. The first one which is of very direct significance to conservation of Lake Victoria Basin is Article 109 on Irrigation and Catchment Management. The provision enjoins the partner States to expand irrigated agriculture and to develop water catchment strategies. In the process the states are urged to improve catchment management as well as rainwater harvesting. Further, and again crucial for reasons already examined herein, is that the parties undertook to adopt and promote use of environmentally sound methods of land use.

Article 111 covers general "Environmental issues and Natural Resources" and urges states to ensure that precautionary measures are taken to avoid negative impacts of development activities. Specific emphasis is placed on cooperation in management and coordination of policies to promote sustainable development; control of transboundary movement of hazardous wastes; and to ensure sustainable use of

lakes, wetlands, forests and other aquatic and terrestrial ecosystems. Parties are also urged to promote capacity building for sustainable development. The provisions of Article 112, entitled "Management of the Environment" is, in several ways similar to the foregoing ones. However, it has some focus on prevention of environmental degradation in general; development of special strategies for fragile terrestrial and aquatic ecosystems; as well as control of noxious emissions and chemicals. States are urged to draw up plans for disasters of different kinds.

There are provisions requiring the partner states to adopt common regulations, standards and as appropriate economic incentives to promote compliance. Again they are urged to develop-capacity for implementation of the management and regulatory measures. Environmental impact assessment is given particular emphasis. Article 113 has particular focus on collaborative measure for protection control of movement of hazardous chemicals and wastes and urges for harmonization of regulations for *inter alia,* implementation of regional and global agreements. Article 114 urges for rational management of natural resources, particularly through afforestation and catchment conservation; protection of water resources and establishment of a body to manage Lake Victoria.

Regional cooperation in research and data collection and management centres are urged as mechanisms to facilitate exchange of information on planned projects. Finally, there are novel provisions on mining and exploration for hydrocarbons where the states are urged to develop common procedures and regulatory frameworks. Wildlife management is given a special treatment in Articles 116 which urges the contracting parties to develop collective and coordinated policy for sustainable utilization of wildlife. They agreed to take measures to ratify or accede to and implement relevant international agreements. The treaty evinces considerable enthusiasm over environmental matters. It is clearly desirable that a regional institution be established as already urged. Although the treaty has been domesticated in Kenya its implementation in terms of clear directives are clearly desirable. The regional institution would then thereafter be responsible for coordinating implementation.

Memorandum of Understanding

A Memorandum of Understanding between Kenya, Tanzania and Uganda was signed by Permanent Secretaries for Environment at UNEP Headquarters in Nairobi on 22nd October 1998. This was the culmination of about 30 months deliberate exercise on how to develop and harmonize environmental laws of the three countries. Done under the aegis of UNEP/UNDP Joint Project on Environmental Law and institutions in Africa, the exercise brought together a broad cross-section of senior government officials and academics to be involved in the study which covered seven issues, namely forestry; wildlife; environmental impact assessment; environmental standards; hazardous wastes; toxic and hazardous chemicals; Lake Victoria Basin. Each of the topics was handled by experts at national level and subjected to national consensus building workshops, after harmonization at the regional level.

A meeting of the three permanent secretaries of environment from the three countries were so impressed by the process and the harmonized thematic documents that they urged for preparation of a legally binding agreement on environment for East Africa. In view of the fact that the treaty for the establishment of East African Community, as a framework instrument, under which an environment protocol would fall, was still evolving, it was inappropriate to proceed with work on the legally binding principle. It was, however, possible to develop what was considered a "soft law" instrument in form of a Memorandum of Understanding, which was accordingly developed and signed at the level of Environment Permanent Secretaries. A number of the experts involved in the Joint Project were also participants in the negotiation for the framework treaty harmony with the treaty text.

Standing alone, the Memorandum is a soft law instrument, not binding as such. The important point is that Article 142 the "Saving Provision" of the 1999 Treaty has recognized the Memorandum as one of the nine instruments, which do not lapse with the coming into force of the treaty. Instead, such instruments have legal effect so long as they are construed in a manner consistent with the provisions of the treaty. Therefore the Memorandum has legal significance and may be resorted to in the interpretation and application of the framework treaty and that justifies its discussion in this study.

At the substantive level the Memorandum declared that the partner states agreed to cooperate to ensure implementation activities which demonstrate sound environmental management practices. Very particularly they undertook to strengthen cooperation in development of common water quality programmes as well as measure to reduce and control degradation of environment and natural resources. They emphasized the necessity of developing common strategies to promote proper stewardship over land use and to prevent desertification. Similarly they urged the parties to promote efficient use of water and to institute programmes of flood control. On fisheries, the parties agreed to conduct stock assessment and to determine the optimum sustainable yield.

Management of Lake Victoria ecosystem, which would coincide with the basin, is the subject of a separate Article 7. The partner states agree to initiate, develop, harmonize and implement policies and laws which strengthen regional cooperation in the management of the ecosystem of the basin. Specifically, the management should include fisheries, water quantity and quality, land use, mining, wetlands and other resources for the benefit of the people of the area. Alien genetic resources, including exotic species of flora and fauna are to be regulated and, where appropriate, prohibited. Finally, the parties agreed to cooperate in prevention of pollution of the Lake particularly from industrial and municipal wastes as well as from shipping and transportation.

To support these initiatives, the parties agreed to develop and harmonize standards and legislation applicable to environmental management with a view to preventing all sources of degradation. To strengthen the preventive and precautionary measures the parties undertook to develop and harmonize their environmental impact regulations.

The three countries agreed to develop and strengthen institutional mechanisms at national and regional levels for sustained development and enforcement of appropriated standards and laws. These can be realized only if there is a capacity building programme, which provides harmonized training in matters of environment and sustainable development. Any dispute arising from interpretation or application of the Memorandum is to be handled by negotiation, failing which recourse may be had to the mechanism adopted under the new procedures and institutional structure to be created by partner states within the framework treaty which was still anticipated.

Regional Fisheries Agreement

The only fisheries agreement applicable to Lake Victoria is the Convention for the Establishment of the Lake Victoria Fisheries Organization (LVFO) adopted by Kenya, Tanzania and Uganda at Kisumu in Kenya on 30th June 1994. The convention was developed with the assistance of the Food and Agriculture Organization whose Director-General became the depositary. The general objective of LVFO is to foster cooperation among the parties to harmonize national measures for sustainable utilization of the lining resources of the Lake and to adopt conservation measures. Specific objectives include, *inter alia* building of institutions which can facilitate the general objective either within the region or with international organizations. Presumably building of management measures and institutions include also development of implementing statutes and regulations.

The agreement provides for permanent secretariat for LVFO and that was established and located at Jinja. It is primarily a coordination institution without executive or enforcement powers. The executive secretariat is backed by an Executive Committee and two technical committees. The highest political organ is the Council of Ministers. It is expected that LVFO will be empowered to deal directly with controversial issues such as cross-border fishing that has tainted the relation among the three countries rather badly. There is room for adoption of regulations applicable to all parts of the lake rather than expecting fishermen to be aware of and abide by each country's regulation. Additionally, it may be required that fishermen land their catch at the nearest landing beach and to pay taxes according to agreed scales. This would, of course leave Kenyans at a disadvantage since they are the ones likely to be fishing in the waters of the two other countries. On the other hand if the boundaries were removed and the policing duty were done by a collective institution, this may be avoided. Definitely the LVFO role will have to evolve further and perhaps urgently.

Protocol for Sustainable Development of Lake Victoria Basin

Article 151 of the framework treaty empowers the partner states to conclude. "…Such Protocols as may be necessary in each area of cooperation …". Such a Protocol is expected to spell out the objectives and scope of, and institutional mechanisms for cooperation and integration. The Protocols which are subject to approval by the Heads of State and Government, on recommendation of the Council of Ministers thereafter, constitute an integral part of the framework treaty.

The first protocol that was adopted under the treaty is Protocol for Sustainable Development of Lake Victoria Basin, done at Arusha on 29th November 2003 and signed by the three Heads of the State and Governments. Throughout the 1990's, while the framework treaty was evolving, the global donor community, particularly from Scandinavia and Nordic States, were particularly fascinated with the prospects of planning for sustainable development in Lake Victoria basin. This provided an extra impetus to the negotiating process as the three parties anticipated the possibility of enthusiastic flow of resources for development assistance.

Therefore, the first declaration in the protocol was that there would be cooperation among the three countries towards sustainable development within Lake Victoria Basin. Several principles to govern their cooperation and which are consistent with the notion of sustainable development in our definitions earlier may be summarized as follows: sustainable management and utilization of water resources; sustainable management of fisheries; sustainable agricultural and land use practices, including irrigation; sustainable management of forestry resources; rational management and use of wetlands; improvement of health especially sanitation; promotion of sustainable wildlife management, development and maintenance of infrastructure and energy; maintenance of navigation safety and maritime security; and promotion of research, capacity building and exchange of information.

In implementing cooperative development practices the partner states agree to exercise equitable and reasonable use of water resources with indices, which are similar to conditions in the 1997 United Nations Convection on Non-Navigational Uses of International Watercourses. There is an undertaking to protect and conserve the ecosystem of the basin including migratory species of the wild animals. Management and utilization of fisheries resources must be consistent with the requirements of the Convention Establishing Lake Victoria Fisheries Organization discussed above.

The parties agree to develop and harmonize regulations relating to environmental impact assessment, environmental audit and environmental monitoring as precautionary measures of rational management and protection of threshold of environmental sustainability. To promote harmony and complementarity of activities the protocol requires prior notification of planned activities. For activities which may cause deleterious effects on environment the polluter pays principle is to apply. Similarly, users of specific natural resources shall individually or jointly be held responsible on a cost recovery basis. This is partly to ensure that parties, as large-scale users of water, do not expect free delivery of resources. Similarly, the provisions promote sustainability in resource delivery.

The protocol seeks to promote the modern concept and practice of cleaner production by requiring parties to prevent pollution at sources. They also undertake to prevent discharge of municipal wastes into the lake, a problem that is widespread and unmitigated in the large municipalities like Kisumu and Homa Bay. The parties also agree to take measures to prevent non-point source pollution especially the problems arising from agricultural fields and as a consequence of improper land use practices in agricultural and municipal areas. Finally, the protocol urges the parties to enact and enforce laws prohibiting dumping of wastes and hazardous substances into the lake, an insidious practice that has been grossly ignored under municipal laws and practices.

The parties were aware that such wide-ranging expectations are not realizable unless there is also the twin provision of education and capacity building, on the one hand, and on the other an explicit requirement for exchange of information as well as prior notification of intended activities. These are required under Articles 21 and 24 of the protocol. Then Article 22 requires that arrangements be made

for public participation, which is universally understood as a necessary condition in sound and effective environmental management. One of the ways of realizing public participation is environmental impact assessment, which is already discussed above.

The profuse normative provisions in this treaty would be inconsequential without institutional arrangements to ensure implementation. We find that the parties were equally profuse in setting up the institutional framework suitable for purposes of sustainable development. The treaty set up Lake Victoria Basin Commission as the apex body. The principal objectives of the Commission may be summarized as to promote equitable economic growth, including eradication of poverty but with enhanced sustainable utilization and management of natural resources and environmental protection within the basin. It is also the Commission's objective to promote compliance with safety of navigation, which, needless-to-say, includes safety of life and prevention of ship borne pollution. This requires, of course that the Commission must liaise with Intergovernmental Maritime Organization, the U.N. Specialized organization with expertise and role in guiding and coordinating safety of navigation.

As will have been clear, there is a need for an entity to initiate, coordinate and harmonize development of environmental laws at regional level. The Commission has been given that mandate, to ensure effectiveness of this role. The Commission is required to promote capacity building in terms of human and institutional capabilities. This will, in turn be the key to stakeholder and public participation, and is essential for promotion of sustainable development, including implementation particularly of sectoral development projects. To ensure compliance with the standards which the parties are expected to enforce, the Commission is required to conduct monitoring and evaluation of agreed policy actions. Each party is required to submit periodic reports to the Commission of activities conducted in accordance with the protocol.

There is a novel requirement that the Commission should prepare and harmonize negotiating positions for the partner states against any other state on matters concerning Lake Victoria basin. In this requirement the parties have a provision which corresponds to that in the 1959 Agreement between Egypt and Sudan for the Full utilization of waters of the Nile Waters. According to Paragraph V (1) and (2) of the bilateral treaty, Egypt and Sudan agreed that neither of them would proceed to any negotiations with the other countries on matters touching on Nile waters, without prior consultation and agreement between both. In view of this commitment and considering that the Protocol was adopted when negotiations aware proceeding under the Nile Initiative, the three countries could have been more unequivocal in that provision of the protocol.

Recall now that Article 48 of the Protocol states categorically that the Protocol shall take precedence over any other existing agreements relating to Lake Victoria and in case any other agreement is inconsistent with the Protocol, it shall be null and void to the extent of its inconsistency. The partner states also undertake to collectively react to activities by a third party, which threatens damage or injuries to lake Victoria Basin or its people.

The commission has a central bureau headed by an executive secretary to be equipped with sufficient staff to implement its functions. This is one of the four organs of the commission. The others are largely sectoral in their functions to provide links with the national line departments, or leads agencies, which are responsible for implementation and enforcement of the protocol at the national level. It is for this reason that the requirement for periodic reporting by the governments, to the commission on measures to implement the protocol is so immensely important.

SUMMARY AND RECOMMENDATIONS

The most serious environmental problems in Lake Victoria Basin relate to land use especially agricultural practices; destruction of protected areas in terrestrial and aquatic ecosystems particularly to destruction of forests and depletion of fishery resources respectively; and discharge of municipal and industrial wastes which cause pollution. It has been demonstrated in this paper that without exception, there are legal and institutional arrangements in the books to deal with these problems.

Granted, some of the laws may have weaknesses which may include overly lenient and out-dated penal provisions which were enacted during colonial times and which have lost meaning and effectiveness because of inflation. These include the legal arrangements under the Agriculture Act where existing institutional mechanisms allow for enforcement measures that respond to contemporaneous economic situations. They also include provisions under Public Health and Factories Acts where public officers have immense powers, including authority to close operations. The fines may be neither huge nor deterrent. But the effect of frequent action and penalties combined with closure option would no doubt lead to some deterrence.

That the continued environmental degradation in Lake Victoria Basin is actually an expression of lack of political will to ensure that public officers protect the environment is forcefully expressed in deforestation and destruction of forests. It has been repeatedly stressed that degazettement and destruction of forests in Mau and Cherengany hills will result in destruction of catchments and thus endanger rivers flowing into lake Victoria and Kerio Valleys. Yet the practice has continued unabated. If there was political will to protect the catchments it is conceivable that the government could have possibly invoked its powers under Land Acquisition Act, Cap 295 Laws of Kenya Section 6 (1) which empowers the minister to acquire land compulsorily to promote public good or benefit. The option of compulsory acquisition under this Act may not be necessary if the area is gazetted forest in Mau area, unless the land had been allocated to political protégés. Extraordinary situations such as the danger to the catchment, the rivers and the lake justify extraordinary measures, accompanied by massive reforestation.

In more recent times the Water Act, 2002, empowers the Water Resources Management Authority, after consultation with the Minister to declare a “protected area” and impose specific regulations or prohibit conduct of activities which may jeopardize a catchment for which provisions or strategies for catchment management exist. Granted, the Water Act 2002 is new and, according to Gazette Notice No. 10340 of 31st December 2002 the Authority assumed its responsibility only with the date of the gazettement, which means that it has not had time to operate. But subsequently, the Authority can be expected to commence operation by invoking rules which will safeguard the reasons for is existence, namely water resources and their catchments areas.

In reality, the hopes may remain frail, if the Ministry of Water and Irrigation together with the Authority do not depart from the traditional lethargy of line ministries or agencies to date. That lethargy also characterized the conduct of the office of the attorney general, the supposed defender of the public good, at least as far as environmental matters are concerned.

Since 1970 the global paradigm in development and enforcement of framework environmental law took a clue from the traditional lethargy and shifted to enactment and enforcement of the new approach in environmental law. By 1980 Kenya government had recognized the necessity of enacting a framework environmental law but without success. In 1993 there was an agreement nationally that work be commenced towards enactment of such a law. Because such a law is complicated and requires consensus among all line departments, agencies and civil society, it took time but the law was finally enacted as Environmental Management and Co-ordination Act, 199. It created three principal avenues which, hopefully, will deal with the institutional lethargy, though not political will. First the agency created under the Act, NEMA, can intervene on its own to ensure enforcement action by line departments or it can ensure compliance; otherwise the agency can be sued for any environmental degradation. Secondly, the statute empowers the public to participate in protection of the threshold of sustainability. An example of such an avenue is participation in environmental impact assessment. Thirdly, the law provides open access to environmental justice, whereby any person resident is Kenya is legally entitled to seek order from the High Court for protection of environment as such without demonstrating his personal or proprietary interest. The rule of open access to environmental justice in Section 3 of the framework statute is arguably the single most important route to by-pass the inaction in government ministries. The same malady can easily creep into the autonomous environmental agency, NEMA, as was noticed for a full two years when with staff and a budget, it still remained inactive and thus losing the momentum that accompanied the legislative process.

It is therefore curious that the protocol for sustainable development of the Lake Victoria Basin made no provision at all on access to environmental justice. The framework treaty, similarly, makes no such specific provision. However, its Article 30 provision on *locus standi* that allows any person to challenge the legality of conduct by a partner state or its institution before the East African Court of Justice may some day be found to include environmental cases. Jurisprudence on such matters will still evolve with time and the vibrance of local legal practitioners.

There are, however, two novel provisions in the Memorandum of Understanding which, it will be recalled, was incorporated into the framework treaty under its Article 142. Both provisions are in Article 16 of the Memorandum; in paragraph 2 (d) the partner states agree to develop measures, policies and laws which grant access, due process and equal treatment in administrative and judicial proceedings to all persons who are affected by environmentally harmful activities in the territory of any of the partner state. That is, of course only a statement of policy not enforceable as such. On the other hand, paragraph 3 is forthright. Here, the Partner States agree to grant rights of access to the nationals or residents of other partner states to their judicial and administrative machineries to seek remedies for transboundary environmental damage.

For the reasons explained above we put particular premium on statutory rights bestowed on individuals to seek administrative or judicial order on behalf of environment. Courts have not been consistent, when action is based on common law principles. In Uganda, where individuals have relied on both the constitutional and statutory authority the results have been impressive. This is particularly so because of prevalence of public spirited lawyers. Uganda enacted the framework statute in 1995 shortly after adoption of the new Constitution. In Tanzania individuals relying on common law, and in the absence of both framework statute and a direct constitutional authority, have faced problems with sensitive cases. Now with a new framework statute adopted in 2004, some changes may occur. In Kenya, reliance on common law led to very erratic court decisions. But now Section 3 of the framework statute opens a new avenue for individuals to close the gap left gaping by lethargy by government agencies.

The provisions of the framework treaty, the Memorandum of Understanding and the Protocol and the fisheries convention open a new vista in environmental management, to complement the national framework statutes and sectoral and functional laws. All the instruments concur on five basic factors that determine improvement of environmental governance in the Lake Victoria Basin and on which we base recommendations for the future. First, all the instruments agree on the nature of the environmental problems which should be addressed urgently. These include land use practices; catchment protection; protected areas and ecosystems conservation; protection of biodiversity including terrestrial and aquatic resources, and control including proper disposal of wastes. All these are basic concerns at regional level and are in the national statutes with corresponding institutions but there is total failure to enforce. Admittedly, there may still be weaknesses in the normative and institutional arrangements. However, there should first be bona fide efforts at implementations to allow for recognition of the gaps in the law or institutions.

Secondly, there is a uniform agreement that deliberate action be taken to develop and harmonize laws in the main problem areas. There are at least two primary aspects to this. On the one hand there is an urgent need to bring the national sectoral statutes in harmony with the framework statute. It was pointed out earlier that where any statute is in conflict with the framework law then the latter prevails. Therefore, it is essential that deliberate efforts be made to harmonize the statutes with the framework law. Uganda has made some efforts in this direction. Kenya has clearly done so for the Water Act, 2002. It is timely to raise the issue for Tanzania. Methodology for such an activity was evolved through the UNEP/UNDP Joint Project in late 1990's and can be improved upon. This process is urgent for Kenya where many of the sectoral statutes are outdated and may not respond easily to the requirements of the framework statute, let alone the requirements of the modern regional instruments. There could for instance be harmonized codes for public or fisher-folk participation in fishing regulation especially through beach Management units (BMUs) which may be analogous to port state control in fishing in marine environments.

Thirdly, all the instruments call for strengthening of enforcement machineries and procedures, a matter which is grossly wanting in Kenya. We have recognized the overwhelming lethargy in the sectoral agencies as far as enforcement of environmental laws are concerned. On the other hand, NEMA, the agency in which Kenya has invested hope, has been active for only two years, having wasted the first two. So it may not have confronted as many challenges as has Uganda's NEMA. Although it has taken a number of decisions before, the first true test will be Kaputuei settlement proposal being fallaciously touted as wildlife versus the poor controversy. The Director General has rejected the proposed settlement and if he has relied on respectable legal and scientific arguments to advise his decision, he has to wait for available procedures to test the decision. For he must not be seen to have made a capricious decision which would undermine his credibility. His Ugandan counterpart faced such a challenge over decision to reject use of herbicides to destroy water hyacinth on Lake Victoria. The decision was sustained against contrary position of many powerful voices.

Fourth, all the instruments urge for public participation in development and enforcement of environmental law. As pointed out earlier the Kenyan framework environmental law has abundant and appropriate provisions for public participation and access to environmental justice. The mechanisms of environmental impact assessment, environmental tribunal, public complaints committee, and courts of law with the open provision for *locus standi* have barely been used in the four years. The civil societies were active, sometimes violent, in seeking environmental protection at a time when only common law remedies were available. When the framework law came into effect in January 2000 many observers feared that there would be a floodgate of litigations. Unfortunately, there has been deafening silence. Even lawyers who have been sensitized on the issues through national and regional workshops on access to environmental justice have largely remained inert. The situation in Tanzania and more so, Uganda has been vibrant. A way must be found to stimulate public participation in development and enforcement of environmental law in Kenya. NEMA cannot be expected to stimulate a source of challenge to their work.

The fifth basic matter recognized by the regional instruments is capacity building and awareness creation. This is particularly necessary because environmental law is a fairly new field of study and a practice. This necessitates a systematic, deliberate, massive and sustained capacity building initiative. At the basic level, it is necessary to make environmental law one of the foundation courses that should be taken by all law students. It is also essential to demystify environmental law by making courses available to students other than those studying law in the university. Both approaches will create significant literacy in the field.

Beyond these levels, it is essential to introduce and intensify continuing education in environmental law. Judges, legal practitioners, parliamentarians, policy makers and civil society groups should be targeted. It would be particularly desirable to conduct these short courses at the regional, East African level. It should be possible to have a rapid and harmonious development of regional environmental jurisprudence through judicial decisions and practice, which is also advised by global comparative decisions. The East African Community's environment or legal office could play a coordinating role or simply to find mechanisms for the functions being conducted. Through the Commission, the Sectoral Council and Committee this initiative can be pursued ensuring development, harmonization and enforcement of environmental law. The "peer pressure" effect would possibly help Kenya to move faster and Tanzania to commence early implementation of their new framework statute.

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Valuation of Environmental Assets in the Lake Victoria basin

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ABSTRACT

Chapter 8 of Agenda 21, the programme of action by the United Nations, an outcome of the earth summit in Rio de Janeiro in 1992, advocates for "Making effective use of economic instruments and market and other incentives" in integrating environment and development in decision making. In order to achieve Sustainable Development (SD), economic, social justice and environmental conservation have to be considered simultaneously in an integrated manner. The environmental dimension requires knowledge of what resources our natural environment holds and of what value they are to us. Without this knowledge we might undervalue and abusing the resources to our own detriment. This paper explains the concept of environmental asset valuation and its importance to Sustainable Development. The next section of this paper discusses the concept of environmental assets, what they are and the justification for their estimation. Subsequent sections identify the Lake Victoria basin environmental goods and services and provide comparison between social and economic values. The concept of total economic value and estimation methods for environmental goods and services are also presented. The valuation experiences in the Lake Victoria basin and the valuation gap in the basin as well as the link between environmental asset valuation and environmental resources accounting/natural resources accounting (NRA), environmental impact assessment (EIA) and cost benefit analysis (CBA) are also briefly discussed.

Key words: *Cost benefit analysis, economic asset valuation, environmental impact assessment, environmental value, Lake Victoria basin.*

INTRODUCTION

What are environmental assets in general and why estimate environmental values?

Environmental resources are categorised into goods and services. Environmental goods are also categorised into those which are traded in the goods market, and the non-traded ones, but provide immense livelihood value to rural populations nevertheless. Environmental goods include timber, logs, poles, grass (thatching and pasture) wood fuel, beeswax, bees honey, fish, wildlife, minerals and water, gum, rattan, medicinal plants and edible fruits and plants. Environmental services include ecological functions such as micro climatic regulation, carbon sequestration and storage, soil conservation, filtration of effluent, watershed protection, recreational amenities, habitat for valuable biological resources, and provide many social, religious and cultural benefits to communities (Lange and others 2003). These normally do not have a market, as is the case with other commodities because they are not traded, this is the concept of 'missing markets', and thus are not usually included in private and public development decisions. However, these environmental goods and services, which are not traded in the market, have economic value, which is fundamental to our existence.

The rationale for valuing environmental resources is to ensure their wise use. Many environmental resources are complex and have multiple ecological functions. The state of knowledge currently does not provide us with all the possible uses of these environmental resources to social welfare. Generally,

it is desirable to 'hold on' to these resources un-degraded as opposed to depleting or degrading them. Economic valuation provides us with tools to assist with the difficult decisions involved in the utilisation of our environmental resources. The major application of economic valuation is to avoid the loss of environmental resources especially those with irreversible outcomes.
Each choice or option for the environmental resource, either for leaving it in its natural state, allowing it to degrade or converting it to another use, has implications in terms of values gained and lost. The decision as to what use to pursue for a given environmental resource, and ultimately whether current rates of resource loss are 'excessive', can only be made if these gains and losses are properly analysed and evaluated. This requires that *all the values* that are gained and lost under each resource use option be known and carefully considered.

For example, in order to preserve an area in its natural state, it is required that costs of preservation for setting up a protected area, which may include direct costs (such as monitoring and enforcement costs), and development benefits foregone, are considered as additional costs associated with the preservation option identified through the market.

A similar approach should be taken in evaluating the development options for the environmental resource. In this case, if the environmental resource is to be converted to some other use, not only should the direct costs of conversion be included as part of the costs of this development option but so must the *foregone* values that the converted resource can no longer provide (such as the loss of both important environmental functions and many important biological resources and amenity values as well). Economic valuation of environmental resources is relatively new, most of the valuation work in the world has been done since 1980 (Georgiou and others 1997).

Further justifications for undertaking environmental asset valuation are provided under the informed decision-making and facilitation of: carbon trading, construction of Natural Resources Accounts (NRA), Environmental Impact Assessment (EIA), Cost Benefit Analysis (CBA) and Legal procedures in environmental liability regime among others. Faced with pressure from the increasingly sensitised citizens to take environmental conservation actions and tight budget, governments must make difficult decisions about allocation of public funds for investment to protect, mitigate and or restore the natural environment. Some of these decisions involve tradeoffs between investment in say manufacturing or providing health or educational facilities. These decisions need to be backed up by convincing arguments about environmental quality, threats to ecosystem integrity and quality of life and their importance *vis à vis* alternative investments. Thus decision makers will be called upon to demonstrate the economic benefits of the investments they make in the environment. To do this they have to undertake economic analysis, which will inevitably involve valuation to come up with comparable monetary values. These environmental asset values will be used to facilitate the justification of public spending on conservation, protection, restoration and mitigation investments, create awareness on the value of the environment to the general public. Furthermore, where there exists multiple investment opportunities, these values may enable the comparison of the benefits of different projects and help prioritise conservation and or restoration projects hence maximise the environmental benefits per monetary value spent.

Decisions to invest in a particular project or even comparison between projects are facilitated by the use of Cost Benefit Analysis (CBA). The traditional CBA uses market-generated data for its analysis. The economic analysis imputes some proxies for time use into the CBA particularly in the water supply projects. Environmental values also need to be accounted for in the costs and benefits as well. Hence, environmental valuation comes in handy when we need to include all traded and non-traded benefits and costs. For example, in the case of conversion of a wetland for settlement or any other economic use (say construction of a hotel), wetland benefits will have to be compared with the benefits accruing to people when the wetland is converted and a hotel is constructed in its place or part of it. Wetland benefits include the control of floods, filtering toxicants, pollutants and sediments before they are introduced into major water bodies. Coastal wetlands reduce shoreline degradation while most wetlands are important habitats for rich biodiversity; provide feeding grounds and refuge for certain species and transit stations for migrating birds. Many wetlands have unique landscapes, providing aesthetic values of tourist significance. Communities around wetlands have depended on wetlands for their livelihoods

particularly for water and nutritional supply of fish. Other uses include traditional building and craft materials, extraction of resources for economic benefits such as fish and papyrus for making mats and chairs. Traditional ceremonies and cultural practices are performed in wetlands; such communities have a lot of attachments to wetlands.

Most of the wetland benefits accrue to the public in general while the hotel's benefits accrue to a private entrepreneur. Although the hotel may create employment to the local community and provide a market for some of the locally produced goods, practice has shown that these benefits are normally minimal due to the argument that local communities do not have the required skills and their locally produced goods do not meet the required standards! All in all to be able to decide which will be the most beneficial decision, a CBA has to be done, that which includes all tangible and intangible benefits, traded or non-traded.

Another important precautionary measure for environmental protection is the process of Environmental Impact Assessment (EIA). This approach espouses caution in any activity which potentially may harm the environment be it social or economic or otherwise. It plays a pre-emptive role in trying to avoid damage at the planning stage. Hence the feasibility of an activity e.g. project will be preceded by this study which includes various specialisations cutting across social sciences (economics, socio-cultural, geography, etc) to natural sciences (zoology, marine biology, botanical sciences, chemical, physics, geology, etc). Environmental asset valuation will facilitate attempts to quantify and express in monetary terms the values to be included in the feasibility analysis using CBA.

Valuation of environmental goods and services plays a very important role in terms of providing vital and useful information for accounting for environmental resources presently not accounted for by the national accounts. NRA is a vital tool, which provides the necessary information needed in order to enable us to understand the status of the wealth and health of our environment. NRA provides better measures of economic performance compared to the System of National Accounts (SNA) by linking problems such as land degradation, groundwater depletion, deforestation, pollution, to economic activities producing them on one hand and affected by them on the other. SNA alone cannot accomplish this because it is mainly based on marketed transactions for its data requirements, whereas NRA incorporates non-market use and non-use values of environmental goods and services. By accounting for the stocks and flows of the natural resources, we are able to determine whether we are overdrawing from our natural resource accounts. NRA also helps in determining whether we are able to balance the rate of consumption and that of replenishment of our resources. This is an important aspect in resource accounting because for development to be sustainable, the amount withdrawn should not exceed the amounts reproduced or regenerated.

NRA accounts for both Renewable and Non Renewable resources. For the renewable resources, accounting is very much focused towards the balancing act between consumption and regeneration in order to ward off depletion and also sustain consumption through converting the natural capital into man made capital. The non-renewable resources however do not have the ability to regenerate and therefore their focus is mostly on their ability to sustain consumption through sustainable income and by wise investment of their proceeds in terms of converting natural capital into other capital forms particularly man made capital for sustaining consumption through the maintenance of constant capital (Hicks 1942; Solow 1986; Pearce and others 1996). By accounting for our environmental assets together with those accounted for by the SNA, we are then able to reflect the real wealth of our nations and not understate or overstate it in some cases by partial accounting.

Market approaches for environmental resources management have received much attention recently due to their efficiency and flexibility among other qualities. However, the enforcement of environmental laws needs a clear environmental liability regime to base legal decisions such as compensation aspects of the liability. Valuation comes in to fill this gap although amid several difficulties or controversies. Swanson and Kontoleon (2003) assessed the US experience with using CBA in courts with the aim of providing suggestions as European legislators formulate the direction of the EU environmental liability

regime[21]. They found the US experience bumpy and riddled with issues of: accuracy and high cost of valuation studies for non use environmental values, inconsistency of valuation with the compensation aspect of new liability and issues of legal standing regarding both use and non use values i.e. whose preference matters for consideration in terms of suffering *real* loss in the event of environmental damage of an amenity enjoyed by all?[22] Despite these pitfalls, they nevertheless concluded that valuation has a role in civil liability. Courtroom experience in the US shows successful use of Contingent Valuation technique for the estimation of environmental damages.[23] However it still needs further work to solve the critical issues raised above to make it compatible with legal standing requirements and courtroom directed valuation.

Carbon offsets is a new kind of policy instrument for forestry, it offers international subsidies or financial incentives to help mitigate climatic change through carbon storage in natural reservoirs like soil and forests[24]. It is widely known now that deforestation reduces the capacity of forests to sequester carbon dioxide and reforestation and afforestation has the opposite effect to carbon sequestration and storage. Various funds have been developed recently to cater for carbon payments by the Carbon Fund, the Global Environmental Facility (GEF), and even individual countries and firms[25]. Developing countries can apply to receive these funds, which therefore act as an incentive to conserve and even develop the capacity to store more carbon. In order to know the capacity for carbon storage, computations have to be made in order to estimate this value[26]. Market instruments for environmental management and control are also knocking on the area of trading in environmental non-use values. The Kyoto Protocol of the Framework Convention on Climatic Change could link the carbon sequestration role of forests to the market for tradable carbon emission permits. Developing countries will be able to claim credits for carbon sequestration that occurs in the period 2008 to 2012 in forests established after 1990 on land not forested prior to 1990[27].

The concept of Total Economic Value (TEV)

Total economic value identifies two major categories of benefits/values. The first category is that of *use values or benefits*, which are benefits accrued to individuals out of actual direct and indirect use of environmental resources. In this category we may group a fisherman, hunter, timber trader, firewood cutter/collector, wild mushroom collector, honey harvester and others who are actually using the natural resources and derive benefits from them either financially or livelihood wise. In this category we may also include those who are enjoying the environmental services albeit in an indirect non-consumptive way such as swimmers, bird watchers, hikers or trekkers among others. The second category is the *Non use values or benefits* which include *option values, bequest values, existence values and aesthetic values.* Option values are “essentially an expression of the willingness to pay for the preservation of an environment against some probability that the individual will make use of it at a later date” (Pearce and Turner 1990). Option value benefits arise in situations where irreversibility might occur when a resource is depleted. This is different from the bequest value, which is the consideration of intergenerational equity aspects. It is the willingness to pay to preserve the environment for the benefit of our children and grandchildren. People worry about the future generations need to use and experience the environment as we do at present implying that the future generations have the right to these environmental resources just like us and therefore it is our responsibility to conserve the resources for them. Bequest benefits belong to the stewardship benefits category together with existence value. These are moral benefits

21 The proposed EU environmental liability directive is likely to pave the way for the use of economic tools for natural resource damage assessment (NRDA) in European courts.
22 This aspect concerns the use of valuation techniques in court e.g. the CVM that in essence is based on “stated preference” of respondents.
23 These include the Exxon Valdez oil spill off the shores of Prince William Sound in the state of Alaska, whose damages were estimated to lie between US$3 to 15 billion and were settled out of court for US$1billion. (See Swanson and Kontoleon (2003) for more cases.
24 See Sterner (2003) pp 412.
25 Ibid. pp 413
26 See Hassan (2003) pp 43-52 for the discussion of these methods.
27 See Heal (2000) pp71 – 86 for a detailed discussion on how the global market for carbon works.

that people derive from knowing that they are fulfilling their role as stewards of the worlds' resources. Existence value is the expression of the desire for a certain resource to exist for its intrinsic value and not necessarily for its use value or otherwise. Endangered species of flora and fauna may qualify in this category. These are species, which have been in existence and we would like them to continue to exist into the future. Table 1 presents a taxonomy of the various categorisations comprised in the Total Economic Value equation.

Table 1: Taxonomy of Economic Values.

Use Values/Benefits		Non - Use Values/ Benefits			
Direct Use Values (DUV)	**Indirect Use Values (IUV)**	**Option Values (OV)**	**Bequest Values (BV)**	**Existence Values (EV)**	**Aesthetic Values (AV)**
(Outputs directly consumable or consumptive uses) e.g.	*(Ecological functions and non consumptive use benefits) e.g.*	*(Deferred Use of Resources both direct and indirect use values) e.g.*	*(Use and non use values of environmental legacy) e.g.*	*(Benefits by virtue of existence of resource) e.g.*	*(Appreciation of beauty of the natural environmental amenities) e.g.*
Wood products	Carbon sequestration	Future personal recreation	Recreation	Preserving biodiversity	Beaches
Hunting	Watershed protection	Future Consumption	Future Consumption	Landscapes e.g. mountains, craters, etc	Landscapes
Water	Biodiversity	Biodiversity	Habitats	Habitats	Wetlands
Minerals	Filtration of effluent	Conserved habitats	Prevention of irreversible change	ecosystem	
Fish etc	Religious and cultural benefits				

ESTIMATION METHODS FOR ENVIRONMENTAL GOODS AND SERVICES

There are several approaches/methods to the valuation of environmental assets; each approach is suitable for different environmental benefit situations. These include the stated preference of Contingent Valuation Method (CVM), which is used to assign monetary values to non-use values of the environment. These types of values do not involve market purchases and may not involve direct participation. They include the ecological functions, aesthetic values of the enjoyment of scenic views or wilderness experience, option values, existence values and bequest values. Revealed preference methods of travel cost and hedonic prices/indices, the former mostly used for valuation of environmental amenities which do not involve direct market purchases but use what is known as a "surrogate" market of travel costs involved in getting to the environmental resource such as wildlife viewing or coastal tourism. Hedonic prices approach is mainly used for valuing environmental quality in terms of prices of houses as a proxy. Other methods include cost based valuation such as the replacement cost technique.

Stated Preference Method (CVM)

A considerable literature has grown on the valuation of non-market benefits where the CVM has emerged as the most employed approach in valuing *non-use values* of the environment. It is, however, used also for *use values* like water supply project studies particularly in the rural areas. It is based on asking people questions about their preferences in terms of their willingness to pay (WTP) for a certain environmental service or resource's existence, preservation or avoidance of damage. Alternatively, WTP is the total amount of money an individual would give up in exchange for all the benefits associated with an environmental resource. The opposite is the willingness to accept compensation (WTA) for a degraded (or conversion of an) environmental resource such as a wetland among others. It is the minimum total amount of money an individual would accept to forego all the benefits associated with an environmental resource. Normally WTP<WTA, since WTP is bounded from above by an individual's budget constraint. These values are then taken as the manifestation of what benefit people in a certain locality ascribe to the environmental resource in question.

Revealed Preference Methods

Hedonic valuation

Natural resources can be thought of as bundles of characteristics such as recreational, consumptive and aesthetic appeal characteristics. These characteristics vary in type, quantity/scale and quality across resources. The hedonic price of a resource therefore reflects the various combinations of characteristics as well as various levels of quality and quantity or scale. In this sense therefore, an environmental resources' quality may be reduced through pollution, which will be manifested by the reduced quality of some of its characteristics. The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. It can be used to estimate economic benefits or costs associated with: environmental quality, including air pollution, water pollution, or noise.

The hedonic pricing method is most often used to value environmental amenities that affect the price of residential properties. For example, lets hypothesise that House Price (HP) depends on the four housing characteristics of distance (D) from and to work place, house size (HS), lot size (LS) and noise (N) as follows;

$HP = \alpha + \beta_1 (D) + \beta_2 (HS) + \beta_3 (LS) + \beta_4 (N)$

Where;
α = intercept (scale effect)
α_1 = marginal value of a unit of distance (measured in kilometres, mile etc)
α_2 = marginal value of a unit of house size (measured in square inches, centimetres etc)
α_3 = marginal value of a unit of lot size (measured in acres, hectares etc)
α_4 = marginal value of a having a scenic view (measured in decibels)

The above equation using cross section of individual houses data, will tell us how much on average, house price changes when each of the influencing factors change.

Travel Cost Method

This valuation approach is normally used to measure the proxy values of recreational amenities such as tourist attractions of all kinds. It is thought that we can measure the value of these environmental resources through people's revealed preferences i.e. by looking at what they are actually doing which is a manifestation of their willingness to pay for enjoying those amenities. Many of these amenities are not purchased in the markets so their value must be inferred from associated expenditures. For example, the value of a recreational facility such as boating on the lake Victoria , can be measured by the opportunity cost of time and travel cost spent on the way to the lake from, say, Nairobi, as well as expenses such as fuel and wear and tear of the car if one decides to drive there.

For example, if the lake receives 10,000 visitors of this nature per month, each spends 4 hours boating, 2 hours picnicking on the lakeshores, 3 hours travelling. The opportunity cost of time is Kshs 1,000/hr for every individual, Fuel and wear and tear of vehicle cost Kshs 700/per hour per visitor. Entry to the amenity is Kshs 500/visitor. Thus the total travel cost is;

Number of visitors (10,000) x {Opportunity cost of time (Kshs 1,000) x total time spent (9 hours) + Cost of fuel & wear and tear (Kshs 700 x 3) + Entrance fee (Kshs 500)
= Kshs 116 million per month.

This is a lower bound estimate on WTP for recreational benefits from the lake, since any visitor who finds it optimal to spend time at the lake must receive at least enough benefit to cover the travel cost. This method may be used to assess the lost recreational value resulting from closure of the lake due to excessive pollution among others.

Conventional market approach

Replacement cost approach

This approach considers the cost of replacing or restoring a damaged asset to its original state and uses this cost as a measure of the benefit of restoration. This approach is widely used because it is normally easy to find estimates of such costs. This technique implies the assumption that complete replacement is feasible.

ENVIRONMENTAL ASSET VALUES IN LAKE VICTORIA BASIN

Most of the studies conducted in the Lake Victoria basin with respect to environmental resources have concentrated on wetlands. Wetlands are ecosystems, which hold immense benefit to human beings. Some of these studies are reviewed below. A study by Mdamo (2003) reported on the buffering capacity of wetlands at Kagondo wetlands in Bukoba, Tanzania. It was observed that the water flowing into the wetlands had low mineral contents, which was evident from low electrical conductivity that ranged between 9.7 and 64.4 µS/cm. A limnological study at Nakivubo wetland reported mainly on the levels of dissolved oxygen, BOD, alkalinity, pH, total coliforms and nutrient loads (Kizito 1989). It was revealed that there was a high level of pollution mainly from organic materials including faecal material. On the Kenyan side a study was conducted to investigate the buffering capacity of River Nyando from Muhoroni to the mouth in Nyakach Bay (Handa and others 2002). The results showed that the bigger the wetland the greater is its ability to sieve suspended solids, absorb chemicals and nutrients in the river water. How the wetlands remove the nutrients, suspended particles and chemicals from the waters is not yet clear.

Mwanuzi (2004) in his wetland research in the Lake Victoria basin, Tanzania pointed out that wetlands were important for social welfare and ecological purposes in the Tanzania side of the lake. Studies on biodiversity in small lakes (wetlands) surrounding Lake Victoria have shown that they harbour high species diversity including fish, phytoplankton and macro-invertebrates (Cooper 1996; Kateyo 1999; Katunzi 2003; Mwambungu 2003; Lyimo and Sekadende 2003). The studies further report that the lakes are also used as refugia for the endangered fish species including *Oreochromis esculentus* and *O. variabilis.*

Studies have also been conducted on the distribution of macrophytes in the wetlands. For example, Katende and others (2002) reported on plant diversity in the Nabugabo and confirmed that the area supports different unique species. A study was also conducted on macrophytes with medicinal potential in Lake Victoria, Tanzania and its surrounding wetlands (Lyaruu and Eliapenda 2003). The results showed that a total of 132 plant species including macrophytes were recorded. Out of these, 31 were found to have a great economic value entho-botanically either for medicinal or other domestic uses. Katende and others (2002) made surveys of plant diversity in the Nabugabo and confirmed that the area supports different unique species.

Brouwer (2002) in the draft paper on the wetlands in Niger indicated that the importance of processes in biodiversity is well illustrated by wetlands. Wetlands are areas where water and nutrients are concentrated. It is the process of concentration that makes the wetlands the most productive and most valuable ecosystems in the world. Because of this productiveness wetlands play a very important role in poverty alleviation. At present the role they play is in agriculture, livestock, rearing fisheries, and the production of natural products.

Shechambo and others (2002), indicated that sustainability as a concept is becoming a basic tenet of development, implying that ignoring or underestimating the immense contribution of the environmental resources to the economies of East African countries is tantamount to creating conditions for destroying the foundation upon which these economies are based. It was further indicated that many activities in wetlands are carried out haphazardly, without taking their long-term productivity into account. In many places, local brick makers and sand miners leave behind gaping holes, a danger and health hazard to both humans and animals in addition to depositing clay and sand into the wetlands making it inaccessible.

On the economic valuation of wetland resources, authors have reported various methods, which have been used (URT 2003; Sinden and others 1995; Smith 1996; Turner and others 1994; Georgiou and others 1997; Perman and others 1996, Babier and others 1997; Okurut and others 1999). The total economic valuation has been widely used as a framework for valuation considering both direct and indirect use values. The framework is not without its practical pitfalls: URT (2003) points out that data collection of actual use is difficult and time consuming especially if the use is illegal making data difficult to obtain. Contingent valuation method, travel costs and replacement costs or restoration costs among others have been among the most used valuation techniques. Sinden and others (1995) while pointing out the limitations faced by the CVM as being the inaccuracies of people's valuations, said "it is an attempt to gain a more or less objective valuation of a benefit which in the past has best been valued subjectively by politicians".

There are other important studies on valuation of environmental resources, which have been done elsewhere apart from the Lake Victoria basin wetlands. These studies include that of Mkanta and Chimtembo (2002) conducted through CEEPA's research grant and the IUCN study on economic assessment of water resources of Pangani River basin, Tanzania. Based on tobacco farming in Urambo district, Tabora region - central Tanzania, Mkanta's study estimated NTFP in the tobacco growing area for fuelwood, building soil, grazing, thatch, timber, edible fruits, edible vegetables and herbs, curving wood and bee products. These were significant values when extrapolated for the whole country and adjustments of the national accounts were to be undertaken; the indication was to increase 1999 GDP by 2%. The IUCN study, like the Urambo study, was area specific focusing on the Pangani River Basin. It contains relevant information with respect to the value of water in different uses such as irrigation, livestock, domestic use, hydropower generation and ecosystem use. In short the value of water in the environment brings up its importance to plants, medicinal or otherwise. The catchment forest study provides a wealth of information about the value of these forests using the total economic value (TEV) approach. The study provides estimates of the potential TEV of US$ 620.4million. It points out that significant contributions to the TEV are also made by values for water, carbon sequestration and NTFPs. However, timber and NTFPs dominate the TEV by accounting for 70% of it.

Other studies are by Moyini (discussed in URT 2003) for the forestry sector in Uganda. The study reports a value for the entire forestry sector; including environmental use and non-use values which when converted to present values at a 10 percent discount rate would be equivalent to US$ 2.47 billion. In Kenya, Emerton (1999) reported a gross annual value for Mount Kenya Forest Reserve of US$77million equivalent to a present value of US$ 770million at 10% discount rate. These are relevant studies, which help to raise awareness of the importance of environmental resources in their totality (i.e. use and non-use values).

What is the valuation gap in Lake Victoria basin?

There is a general consensus about the dearth of studies on the valuation of environmental goods and services in the East African region by a number of authors (Shechambo and others 2002; Kasoma 2003; Mwanuzi 2004; Githui 2003). Shechambo and others (2002) indicated that in the three East African countries there is little quantitative data and information about the economic value of environmental resources or the costs associated with their loss and how this affects national economies and people's livelihoods. Kasoma (2003) indicated that research on wetland ecological services is inadequate and there is very little appreciation of the non-tangible benefits of wetlands among communities. There is an obvious gap in information about non-consumptive uses of wetlands such as eco-tourism.

Mwanuzi (2004) indicated the gaps in studies on conservation status dynamics and biodiversity of wetlands. In relation to the study areas he indicated as needing research consideration, were aspects such as: species richness, abundance and diversity of wetland flora and birds, as well as identification and quantification of economic benefits from macrophyte products.

Githui (2003) indicated that socio-economic studies of wetlands in Lake Victoria region are fragmented and not linked to the ecosystem values of the wetlands themselves. Thus, the sustainability of human

activities was not linked to wetland health. There is need to assess the plant biodiversity, measure productivity and assess its role in nutrient cycling in wetlands.

Some observational points

A major difficulty facing valuation of a complex environmental system is insufficient information on important ecological and hydrological processes that underpin the various values generated by the environment. This is true anywhere in the world that non-traded environmental goods and services will always require extra effort to obtain. To make matters worse, in developing economies, the market is not allowed to function fully to give relevant market price indicators due to existing market distortions. This causes data problems for use in market based models such as hedonic property and wage techniques and that is why they are least used in these countries, while on the other hand, techniques that require primary data collection such as contingent valuation, discreet choice and travel cost techniques are widely used and more successful (Georgiou and others 1997).

NEXT STEPS

The above discussion has revealed that very few studies have been undertaken in terms of investigation of environmental asset values in existence in the basin. More importantly, valuation studies of environmental assets in the Lake Victoria basin have not been encountered by our survey[28]. Some studies exist in places other than the Lake Victoria basin in Kenya, Tanzania and Uganda on economic values of forestry resources. This implies that more effort need to be put in undertaking these type of studies for their importance in providing vital information for decision making. Without adequate and the right information, decisions are likely to be deficient and may result into detrimental outcomes particularly if decision makers do not know the adverse impacts of their decisions or what and by how much values are to be lost as an outcome of their decisions.

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