BIODIVERSITY OF LAKE VICTORIA:

ITS CONSERVATION AND SUSTAINABLE USE

[THE UGANDAN VERSION]

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Executive Summary

Lake Victoria, is important as a source of fish, clean water, an avenue for transport and in scientific study. The native fishery of the lake has collapsed, fish diversity decreased and the environment of the lake deteriorated due to human activities. A Lake Victoria Environmental Management Project (LVEMP) was designed to realise a healthy and varied ecosystem of Lake Victoria which is inherently stable and capable of supporting, in a sustainable way the many human activities in the lake and its basin.

The fish biology and biodiversity conservation sub-component of LVEMP is to provide the knowlect'ge required for sustainable use of fisheries and conservation of biodiversity. This is to be achieved through improvement of infrastructure and manpower, providing information in biology and ecology of fishes' and on biodiversity of flora and fauna, setting up of conservation and education. facilities and demonstrations, preparing of information dissemination materials. and disseminating the

Improvement of infrastructure, manpower and planning involves procurement of equipment and supplies, identiiication and recruitment of project staff, procurement of consultants, long term (PhD & MSc) and short term training, project planning meetings, and conducting of national and regional technical review and harmonisation workshops.

In Uganda field surveys cover inshore and offshore waters of Napoleon gulf, River Nile, Nabugabo lakes, Koki lakes, Lake Wamala and Kyoga satellite lakes.

The biology and ecology of fishes include Nile perch, Tilapiines, *Rastrineobola argentea,* Haplochromines, *Labeo, Bagrus, Clarias, Protopterus,* and trophic ecology of fishes. This includes information on population structure, diet, condition factor and reproductive biology.

Biodiversity conservation includes ecosystem diversity, species diversity, and genetic diversity. Ecosystem diversity covers shoreline, littoral and open water characteristics, water depth, bottom type, water transparency, temperature, oxygen, pH, conductivity, and chlorophyll concentration. Species diversity covers fishes, other vertebrates (mammals, birds, reptiles), invertebrates, phytoplankton, and aquatic macrophytes, their composition, relative abundance, population structure, and distribution. Factors impacting species diversity include the role of rocky, macrophytes & oxygen refugia, introduced species especially Nile perch, water hyacinth, and human exploitation. Genetic diversity covers Haplochromines, tilapiines, *Labeo, Bagrus, Clarias, Protopterus,* and Nile perch.

Setting up conservation and education facilities involves rehabilitation and setting up museum, setting exhibits at Uganda museum, rehabilitation and setting up aquaria at FIRI, setting up aquaria and displays in Uganda Museum, setting up aquaria in Entebbe Zoo, habitat manipulation demonstrations, and mapping out areas for protection.

Preparation ofinfonnation dissemination materials includes writing of books on "Biology and Ecology of Fishes", and on "Biodiversity of Lake Victoria", preparation of booklets, taxonomic guides, brochures, posters, video films, GIS maps of aquatic biodiversity, and CD Rom on taxonomy of aquatic organisms.

lnfonnation dissemination includes training of extension agents, community sensitization workshops, talks to educational institutions, mass media events (radio, TV & press release), national & regional conferences & workshops, international workshops, and organising one international workshop at end of project.

The sub-component is implemented by fish biologists & ecologists, a fish taxonomist, an invertebrate biologist, a phytoplankton biologist, an aquatic macrophyte biologist, a biologists for other vertebrates (mammals and birds, reptiles); a population geneticist, a museum and aquarium attendant, data processing assistants, a secretary, drivers, coxswains, and an extension officer.

The budgetary for the period 1999 - 2002 (in '000 US $) is equipment & supplies (446), training & workshops (452), consultants (240), staff salaries (83), field surveys and office expenses (634), preparation of infonnation dissemination materials sening up of conservation and education facilities (68), and infonnation dissemination (58). Total (2122).

The monitorable indicators are the number of equipment & supplies procured,. staff trained, field trips undertaken & the quantity of data collected, books on "The Biology and Ecology of Lake Victoria Fishes", and on "Biodiversity of Lake Victoria", protected areas identified and mapped, museum rehabilitated and functional, aquaria rehabilitated and functional, habitat manipulation demonstrations in place, technical review workshops & their reports, conferences attended and copies of papers presented, lakeside communities sensitised, brochures, booklets and books; taxonomic guides posters, video produced & distributed, extension agents trained, community workshops & their reports, TV and radio programmes, press releases, and talks to educational institutions.

The highlights of progress so far include acquisition of 4 vehicles, I boat and 4 canoes, one officer on PhD training, students on thesis training at Makerere, one national and two regional technical review workshops conducted, field trips to Napoleon Gulf, Nabugabo and Koki lakes, Lake Wamala and Kyoga Minor lakes, literature survey initiated, rehabilitation of museum and aquaria initiated; content of the two books defined; data on biodiversity of flora and fauna and on biology and ecology of fishes.

Some of the constraints encountered include disruption in flow of funds due to.closure of the project bank, delays in procurement of equipment and·supplies and inadequate project personnel

Chapter 2

Biodiversity Conservation in Relation to Aquatic Resources

Biodiversity is the natural biological capital of the earth and represents important opportunities for all nations. It provides goods and services which support human livelihood. The protection of these assets, and their sustainable exploitation offer the means by which humanity can hope to sustain his own well being. Losing of genes within species, species within ecosystems and ecosystems within regions result into disturbances within the environment and reduces the benefits that the system can supply. The United Nations Convention on Biological Diversity (CBO) which came into effect at the Earth's Summit in Rio de Jeneiro in June 1992 defines Biological Diversity as "the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part;: this includes diversity within species; between species and ecosystems".

Genetic-Diversity

The gene constitutes the raw material upon which evolution acts to produce new species. Maintenance of genetic diversity is important in supplying the variety of organisms on earth. The environment acts on this diversity to produce new species and genetic manipulation has been the source of many exploited organisms especially in agriculture. Conservation of this genetic diversity is therefore important in maintaining the pool from which the earth's needs can be derived.

Biodiversity in relation to Aquatic Ecosystem

The CBO has started focusing a major part of its effort on aquatic ecosystems. Biodiversity of inland waters was a main agenda item for the meeting of the CBO's Body for Scientific Technical and Technological Advice (SBSTTA) that was held in Montreal in September 1997 and for the fourth Conference of Parties (COP) held in Brastislava in May 1998.

The CBO sets obligations for the Parties to document their biological diversity evolve strategies and action plans for its conservation and sustainable use, and equitable use of its components. Uganda is a signatory to the CBO. It is therefore obliged to fulfil the provisions of the convention. This report discusses the' status of aquatic biodiversity in Uganda, identify the threat to aquatic biodiversity, and suggest strategies and action plans to ensure the and sustainable use of its components. The report is part of the overall biodiversity strategy and action plan for Uganda, which was prepared by the National Environmental Management Authority (NEMA). The terms of reference for the aquatic' biodiversity sub-sector component are given in Annex I to this report.

Aquatic Systems of Uganda

Uganda is rich in aquatic resources. Up to 17% of Uganda's surface areas is covered by lakes, rivers and swamps. There are five major lakes (Victoria, Kyoga, Albert and Kwania, Edward and George), about 160 small lakes and a high network of rivers and streams. The

distribution of these lakes is given in Figure 1, the areas of the main lakes is given in Table I and the length of the major rivers is given in Table 2. Lake Victoria is the largest tropical lake and the second largest lake in the world. It has a surface area of 68,800 krn^2, a shoreline 3,450 krn long, a catchment area of 193,000 krn^2, a mean depth of 40 m and a maximum depth of 79m. The lake is shared between Kenya (6%), Uganda (43%) and Tanzania (51 %). Lakes Kyoga and Kwania are located wholly within Uganda. They cover an area of 2047 krn^2. The lakes are shallow with an average depth of 3 m to 4.5 m. Lake Albert is located in the western rift valley. It covers about 5,335 krn^2 and is shared between Uganda (54%) and Democratic Republic of Congo (46%). Lake Edward (2203 krn^2) is shared between Uganda (29%) and the Democratic Republic of Congo (61%). Lake Edward is connected to Lake George via the Kazinga Channel. Lake George is situated astride the equator in the western arm of the East African rift valley at an altitude of914 m. It is a shallow lake with a mean depth of2.5m, a maximum depth of 4m and covers an area of250 krn^2. The lake is wholly in Uganda. Most of the lake is bordered by Queen Elizabeth National Park.

There are about 160 minor lakes scattered in various parts of Uganda but are mainly concentrated in the districts of Kabale, Mbarara, Kyotera and Kabarole in southern Uganda and Kamuli, Palisa, Kumi and Soroti in eastern Uganda. They fall in five groups comprising: Lake Wamala, Nabugabo Jakes, Koki lakes, the minor lakes of western Uganda, the Kyoga minor lakes. Lake Wamala is located in Mubende District. Its area varies from 100 to 180 krn^2 depending on the amount of rainfall. Nabugabo lakes include five satellite lakes (Nabugabo, Manywa, Kayugi, Kayanja and Kitunda) located near the western shore of Lake Victoria. The Kyoga minor lakes complex consist of over 24 small lakes all of which are joined to each other and to the main Lake Kyoga by extensive swamps. The Koki lakes are located in south-western Uganda and consists of lakes Kijanebalola, Kachera, Mburo, Nakivali plus 14 smaller lakes. They are 3 to 4 m deep and are associated,.with extensive swamps. The minor lakes of western Uganda include lakes Bunyonyi, Mulehe, Chahafi, Kayumbu etc. These are mainly volcanic lakes. Uganda has extensive river systems and is the source of African longest river the Nile.. Other rivers include Aswa, Dopoth-Okot, Paget, Katonga, Mayanja-Kato, Mpologoma. The lengths of these rivers is given in Table 2.

Most of the lakes and rivers are associated with wetlands. Wetland ecotones are important breeding and nursery grounds for fish. They reduce contamination of open waters by buffering inputs from the catchment and are used in wastewater treatment. They also assist in maintaining water regimes. Wetlands have valuable products such as papyrus, clay and sand. Unsustainable exploitation of these resources can impact aquatic biodiversity.

Economic Importance of Aquatic Biodiversity

The aquatic systems are important sources of fish, which is the primary food commodity exploited by man. Fish is the cheapest source of animal protein food in Uganda. The fishing industry provides employment for 0.5 to I million Ugandans. It is a major source of income and in 1995 earned Shs 77.9 billion (US $ 78 million) at the landings. It is a major export commodity which currently ranks second only to coffee in export earnings. In 1996 it fetched US $ 40 million in export. Some of the fishes are of scientific value and are valuable in evolutionary and ecological studies. The other aquatic organisms are also

important in maintaining a stable ecosystem. Some fish species are of medicinal value. The algae, macrophytes and invertebrates provide food for fish and are important in sustaining a stable productive ecosystem.

Ownership and use of **Aquatic Resources**

One of the biggest problem facing management of aquatic systems is that of ownership. **All** natural water systems in Uganda are public property. As a result of the fisheries on most of the lakes are open access fisheries where exploitation is not adequately controlled. There is currently no control of fishing effort on all the lakes in Uganda except for lakes George and Warnala where fishing effort is supposed to be controlled by law but this is in reality never effected

Table 1. The major lakes in Uganda

Name of lake	Total Area (km')	Area in Uganda (km')	Depth (m)
Victoria	68800	28655	79
Albert	5335	2913	51
Kyoga & Kwania	2047	2047	7
Edward	2203	645	117
George	246	246	3
Bisina	308	308	

Table 2. The major rivers of Uganda

Name of river	Length (km)
Victoria Nile	426
Albert Nile	257
Aswa	357
Dopoth-Okot	314
Paget	232
Kalonga	182
Mayanja-Kato	175
Mpologoma	173

Source: NEAP (1993).

Changes in Biodiversity in Lake Victoria and its implication on fisheries and ecosystem functioning

The Victoria lake basin contains Lake Victoria and several satellite lakes along witb wetlands. Downstream, it is connected to Lake Kyoga via tbe Victoria Nile (Fig. I). Lake Victoria is tbe second largest freshwater lake in the world and the largest tropical lake. It has a surface area of 68,800 krn^2 and a catchment area of 258,000 krn^2 The lake is shared between Tanzania. (51%), Uganda (43%) and Kenya (6%). Like two otber African Great lakes, (Malawi and Tanganyika), Lake Victoria had very high fish species diversity. These lakes represent the' most spectacular examples of very rapid speciation, best demonstrated by haplochromine cichlid fishes. There were over 300 species of haplochromines in Lake Victoria, of which more than 99% were endemic. Lake Kyoga and the other satellite lakes around Lake Victoria had similar native fish faunas.

The catchment of Lake Victoria encompasses a population of about 30 million people, who depend on it as a source of water and food. Historically, Lake Victoria has been a major source of fish, the cheapest fonn of high quality protein for tbe people around it. In addition, it provides clean water for domestic and industrial use, moderates regional climate, receives waste water, and is an important avenue for transport.

Though fish species diversity in Lake Victoria is still high, it was fonnerly extraordinary. The muitispecies commercial catch comprised of many highly desirable food fishes. Two tilapiine species, *Oreochromis esculentus* and *0. variabilis*, which were endemic to the Victoria and Kyoga lake basins contributed most to tbe commercial catches. Riverine species such as *Labeo victorianus* the "ningu" and *Barbus altinalis* "Kisinja" fonned an important fishery along the rivers of tbe lake basin.

By the 1960's, stocks of native tilapiines and otber large species of Lake Victoria had been reduced by overfishing. Nile perch and four tilapiine species were introduced into many of the lakes in the basin, including lakes Victoria and Kyoga in 1950's and early 1960's to improve stocks of the declining fishery. As stocks of introduced species increased, stocks of most of the native species declined rapidly or disappeared altogether. aftbe more than 300 native species, only *Rastrineobola argentea* (Mukene) remained abundant. Haplochromines dropped from about 80% of the fish biomass in Lake Victoria in 1970s to less than I% in 1980s, and about 200 species are feared to have become extinct. These haplochromines were important as food and were of medicinal, scientific and ecological value. They occupied all trophic levels and played a major role in the flow of energy in tbe ecosystem. They were crucial in maintaining tbe ecosystem that supported other food fishes, as well as the high biodiversity associated with tbe lake basin. Studies of haplochromines played a major role in illustrating how organisms undergo adaptive radiation to produce new species, and how a trophically diverse assemblage can efficiently utilize an ecosystem.

Changes in the fish species diversity were accompanied by otber changes in the fauna, flora and physico-chemical conditions of tbe lake. Phytoplankton composition changed and became dominated by blue green algae. Diatoms composition changed from' a

predominance of *Aulocosira (Melosira),* to *Nitzschia* and very tiny centroids. Algal biomass increased four to five times the values of 1960's, and phytoplankton production doubled. This caused a decrease in water transparency. Zooplankton composition changed from mostly calanoid to cyclopoid copepods. The benthic invertebrate comrnuniry became dominated by chironomid and chaoborid midges. The prawn *Caridina ni/otica,* and molluscs increased in abundance. The concentration of vital nutrients changed. Most notably, the silicon concentration decreased by a factor of 10, and phosphorus and nitrogen increased.

The reduction in native biodiversity left much of the excess organic matter unconsumed. Prior to the big shift in the lake's biological communities, more than halfofthe fish biomass was contributed by taxa specialized in eating algae and detritus, thus converting this source of energy into fish flesh rather decomposing bacteria. This disappearance of fish species along with other factors reduced the ecological efficiency of the lake to the extent that much of the primary and even secondary productiviry (e.g., insects) was no longer consumed. These organisms died and sunk to the bottom where they decayed, depleting the water column of oxygen. The result was development of extreme hypoxia in parts of the lake deeper than 40 m. As a result, large volumes of the lake could no longer support fish or other aerobic life, and mass fish kills associated with the mixing of deep anoxic waters become more common. The increase in algal growth seems to have been stimulated by nutrient inputs from the atmosphere, catchment area and internal mixing within the lake. Changes in regional climate are also suspected to have contributed to increased water column stability, reduced mixing, and persistence of the deep water anoxic layer.

Many species had earlier been reduced in abundance by overfishing. However, the rapid reduction, especially of haplochromine species, coincided with a cascade of changes that began with the sudden increase in populations of the introduced predator, Nile perch. The effects of hypoxia and intense predation probably interacted with competition between native and introduced cichlids, further aggravating the decline of some of the native fish specIes.

Increased Nile perch catches have been a major success in the riparian countries because of increased fish catches, although it is not known whether the exploitation can be sustained. There are no means of eliminating the Nile perch from the lake basin. Furthermore, this would not be desirable because of the enormous economic benefits that are associated with the Nile perch fishery. In order to maintain sustainable populations of the remaining native biodiversiry, conservation programs need to be devised and implemented to ensure the coexistence of all species within the lake basin and a productive ecosystem.

The Lake Victoria Environmental Management Project (LVEMP) was designed to contribute to solving some of these problems. The goal of LVEMP, is: *"to realise a healthy and varied ecosystem of Lake Victoria which is inherently stable and capable of supporting, in a sustainable way, the many human activities in the lake and its basin".* The objectives of the project are to:

a) maximize the sustainable benefits to riparian communities resources within the basin to generate food, employment and income, water, and sustain a disease-free environment;

b) conserve biodiversity and genetic resources for the of the riparian and global community.

c) harmonise nation.al manage.ment programs in order to reverse increasing resource and' environmental degradation,'

The fish biology and biodiversity conservation contributes to objective (b) of LVEMP',

Interaction and interrelationships between different of aquatic ecosystems and their relation to the external environment

Ownership and use of Aquatic Resources

One of the biggest problem facing management of aquatic systems is that of ownership. All natural water systems in Uganda are public property. , As a result of this the fisheries on most of the lakes are open access fisheries where exploitation is not adequately controlled. There is currently no control of fishing effort on all the lakes in Uganda except for lakes George.and Wamala fiShing effort is supposed to be controlled by law. but this is in reality never effected.

Relationship between Aquatic System and the External Environment

In assessing the status of aquatic biodiversity, it is important to identify the different components of the aquatic ecosystem and how they are related to each other and the external environme'nt.

The interactions and interrelationships between different components of the aquatic ecosystems and the external environment is illustrated in Figure 2.

The aquatic ecosystems itself consists of primary producers (algae and macrophytes). The production process itself is determined by solar energy and nutrient inputs. These pnmary' products form the food of higher levels (invertebrates and fish), The invertebrates themselves are eaten by fish and some fish also feed on·each other. When different aquatic organisms die, they fall to the bottom of the lake and here form the food of detritus and benthic feeding organisms including fish. The final product out of the lake is fish which is harvested by The aquatic systems are surrounded by wetlands or riparian zones which link the aquatic systems to the terrestrial environment.

The aquatic systems receive water from the catchment area (watershed) and from the atmosphere (airshed). This water can contain pollutants from industrial, agricultural, urban. and forest activities. All these materials end up in the lake and different impacts on aquatic biodiversity.

Besides the fisherfolk who harvest the fisheries, there are many groups who interact in management of the resources. These include government and non-government organisations, researchers, collaborators and donor agencies. These groups play an important role in conservation and sustainable use of aquatic resources.

The status of these different components will be examined in more details. It is important to realise at the onset that conservation and sustainable use of aquatic biodiverisity will require adequate understnding and management of the different components of the aquatic ecosystem and the external environment affecting it.

Figure 2.

Components of Aquatic Biodiversity

Aquatic ecosystems includes not only target plants and animals especially fish, which are harvested by man but also includes many microbial, plant and animal species that, together sustain the stability of the environment. The future of fisheries depends upon management of the different components of the ecosystem and not on management of the target species alone.

Freshwater primarily consists of the water body itself. However the body of water is affected by inputs from the watershed and the airshed. Activities in both the watershed and the airshed affect the structure and functioning of the aquatic ecosystem and determines the types and diversity of organisms themselves. The diversity of organisms is determined by the number of different types of habitats. Organisms can be adopted to live in the near shore littoral zone, as bottom dwelling benthic organisms, as free floating planktonic life, attached to plants and other animal (periphyton), in open water areas (Jirnnetic zone). Destruction of any of the habitats affects the organisms utilising them and can cause their extinction and reduce overall diversity.

The diversity of organisms in an ecosystem is also determined by the trophic level that it occupies the ecosystem. Some organisms are specialised to feed of phytoplankton, bottom deposits (benthos), on zooplankton, or fishes. Depletion of the type of food, especially for highly specialised organisms can cause their extinction.

Primary production processes in a water body are determined by the concentration of nutrients and by the physico-chemical conditions prevailing in that system. Conservation of aquatic biodiversity therefore, depends on proper management of all the vital parameters that support and determine production processes in an aquatic system.

Primary production of phytoplankton is determined primarily by light, temperature and nutrient concentration. These will determine the types, sizes and number of phytoplankton present in the lake. The phytoplankton are eaten by the higher trophic levels, primarily zooplankton. The materials which die and drop to the bottom are eaten by benthic organisms especially macro-invertebrates. These organisms are eaten by fish which is finally harvested by man. Its is this association which determines the biodiversity of organisms in an aquatic system and other organisms.

The trophic Cascade Theory

The relationship between organisms can be explained using a trophic cascade theory. Increased nutrient loading into the aquatic ecosystems could come from the catchment, precipitation, or from internal recycling. Nutrient inputs from the catchment area can increase due to changing land use practises, in particular, increased use of fertilisers, devegatation, and growth of human population. Internal nutrient recycling in aquatic ecosystems mainly occurs through mixing and upwelling. Feeding and excretion by fish and zooplankton release nutrients and enhance internal recycling of nutrients.

According to the trophic cascade theory, changes in the composition and abundance of a piscivores' (fish) can alter composition and abundance of planktivores (micro and macro-invertebrates). Then grazing by the planktivores can alter the composition and of algae (Carpenter et al. 1985).