Wetlands, Biodiversity and Water Quality Status of Lake Cyohoha South Sub-Basin

Nile Transboundary Environmental Action Project

Nile Basin Initiative

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The Nile Transboundary Environmental Action Project.

Foreword

The Nile Basin Initiative (NBI) is a partnership between riparian countries of the Nile; namely Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The NBI's shared vision is to "achieve sustainable socio-economic development through the equitable utilisation of, and benefit from the common Nile Basin water resources". To translate this shared vision into action, there are two complimentary programmes: the Shared Vision Programme (SVP) which creates a basin wide enabling environment for sustainable development; and the Subsidiary Action Programmes (SAPs) engaged in concrete activities for long term sustainable development, economic growth and regional integration of the Nile Basin countries.

The Nile Transboundary Environmental Action Project (NTEAP), one of the projects under the NBI's Shared Vision Programme, is mandated to provide a strategic environmental framework for the management of the trans-boundary waters and environmental challenges in the Nile River Basin. One of the ways in which NTEAP met this objective was to conduct studies to improve the understanding of the relationship between water resources, development and the environment; enhancing basin wide cooperation and capacities for better environmental management of Nile Basin resources.

This study was initiated by the Wetlands and Biodiversity Conservation component of NTEAP to promote the understanding of the functions of wetlands, biodiversity and water resources in sustainable development. The study was a response to requests by the Nile Equatorial Lakes Subsidiary Action Plan Cordination Unit (NELSAP-CU) which envisaged a series of investment and development projects in the Lake Cyohoha Sub-Basin. The selection of the study area took into account preliminary observations that there are already ongoing and proposed interventions which would benefit from the in-depth study on water quality, wetlands and biodiversity. The sub-basin catchment, its wetlands and forests are very important natural resources and are habitats for biodiversity on which the livelihood of the communities living around the sub-basin evidently depends. The results of this study serve as a baseline to guide future investement programmes for this area.

Studies on limnology and water quality were done to complement the wetlands and biodiversity surveys so as to propose solutions to the major threats facing the lake and its associated wetlands. Some of the threats include rapid population growth and agricultural activities, unwise land use practices, intense erosion and silt loading in river and lake basins, severe organic nutrient pollution, wetland drainage and un-sustainable water usage. The ecological processes, impact of wetland modifications, status of water quality, habitat and biodiversity have been studied. This report is the first attempt to address the threats of a degrading eco-system.

In this study, it has been established that Lake Cyohoha South's limnology has changed over the years with significant changes in its morphometry, turbidity, high rates of retention of nutrients and organic matter and low water retention time (WRT), which may have had an effect on its biodiversity. It has also been established that as wetlands continue to be hotspots for biodiversity, they provide a buffer to the chocking sediments from the catchment and hence should be conserved.

An assessment of the economic value and major threats, together with the underlying socio-economic functions has been made for effective management of the sub-basin resources. The wetland vegetation along with other unique species is harvested for fodder, decorations and making fishing boats and mats. The forest vegetation is harvested for sale or domestic use as fuel wood. People also harvest the wetlands and forest products for various uses including commercial purposes. This implies that guidelines to sustainable utilisation of the resources should be devised, including massive sensitisation to reduce the loss of wetland habitat and reverse their degradation that has occurred in recent years.

The result of this study has also recommended that Lake Cyohoha and its wetlands qualify for the special status of being a trans-boundary Ramsar Site. It has potential for eco-tourism and other investment opportunities based on existing wetlands and their biodiversity. It is therefore imperative to establish a management authority to cordinate efforts of Rwanda and Burundi to harness the full investment potential of the sub-basin. The authority shall strengthen the current institutional efforts to regulate sustainable best practices for wetlands and biodiversity management of these trans-boundary resources.

We hope that this study contributes towards research in the field of wetland management in the sub-basin. Continued appropriate data collection will fill the gaps identified in the study to monitor and strengthen management measures for the wetlands and biodiversity in the sub-basin.

Gedion Asfaw
Regional Project Manager
Nile Transboundary Environment Action Project.

Abreviations and Acronyms

ABO :	Association Burundaise pour la Protection des Oiseaux
ACNR :	Association pour la Conservation de la Nature au Rwanda
ADB :	African Development Bank
AM :	Afrotropical Migrant
Bio. Control :	Biological Control
BU :	Burundi University
CBD :	Convention on Biological Diversity
CBO :	Community Based Organisation
CFM :	Consultant Firm Member
CGIS :	Centre for Geographical Information System
CEPGL :	Communauté Economique des Pays des Grands Lacs
CNECN :	National Institute for Environment and Conservation of the Nature
COMESA :	Common Market of Eastern and Southern Africa
CRS :	Catholic Relief Services
CSO:	Civil Society Organisation
DGFTE :	Direction Générale des Forêts, du Tourisme et de l'Environnement
DPAE :	Direction Provinciale de l'Agriculture et de l'Elevage
E :	Endangered
EANHS :	East Africa Natural History Society
Ec. Import:	Economic importance, ecological role
Ecosystem:	A self-regulating community of living things in their physical and chemical environment.
Eng.:	English
FACAGRO :	Faculté d'Agronomie
FAO :	Food and Agriculture Organisation
UNFA :	United Nations Organisation for Food and Agriculture
FIDA :	Fonds International de Développement Agricole
GEC :	Green Environment Conservation
GDP :	Gross Domestic Product
GPS:	Geographical Position System
GoR :	Government of Rwanda
HIMO :	High Intensity Manpower (Labor Intensive)
HIMO :	Haut Intensité de la Main-d'œuvre
HLIS :	High Learning Institution Student
IBA :	Important Bird Area
IGEBU :	Institut Gégraphique du Burundi
INCN :	Institut National de Conservation de la Nature
INECN :	Institut National pour l'Environment et la Conservation de la Nature
IRAZ :	Institut de Recherche Agronomique et Zootechnique
ISTR :	Institute of Scientific and Technological Research

IRST :	Institut de Recherche Scientifique et Technologique
ISABU :	Institut des Sciences Agronomiques du Burundi
ISAE :	Institut Supérieur d'Agriculture et d'Elévage
ISAR :	Institut des Sciences Agronomiques du Rwanda
ISP :	Institut Supérieur Pédagogique
Kd:	Kirundi
Kn:	Kinyarwanda
IUCN	International Union for Nature Conservation
KIST :	Kigali Institute of Science and Technology
LC :	Least Concern
MAO :	Ministerial Agency Officer
MINAGRI :	Ministère de l'Agriculture et des Ressources Animales
MINATETAP :	Ministry of Environment, Land Developmet and Public Works
MINECOFIN :	Ministère de l'Economie et des Finances
MINITERE :	Ministère des Terres, Environnement, Forêts, Eau et des Mines
NBI:	Nile Basin Initiative
NGOs :	Non Government Organisations
NELSAP :	Nile Equatorial Lakes Subsidiary Action Project
NEPAD :	New Partnership for African Development
No doc :	Not documented
NT :	Near Threatened
NTEAP:	Nile Transboundary Environmental Action Project
NTU :	Nepherometre Turbidity Unit
NUR :	National University of Rwanda
ROTNP :	Rwanda Office of Tourism and National Parks
PASTA :	Plan Stratégique de Transformation Agricole
PDL-HIMO :	Programme de Développement Local-Haute Intensité de Main d'Oeuvre
PM :	Parlaearctic Micrant
PNUD :	Programme des Nations Unies pour le Développement
PSTA :	Plan Stratégique de Transformation Agricole
Q :	Quantity
R :	Resident
RADA :	Rwanda Agricultural Development Authority
REASON :	Rwanda Environmental Awareness Services Organisation Network
REMA :	Rwanda Environment Management Authority
SGP:	Small Grants Programme
SSG :	Site Support Group
Sp. :	Species
TSD :	Technical Service of District
UICN/IUCN :	International Union for Nature Conservation
UNDP :	United Nations Development Program
UNEP :	United Nations Environnent Program
WHO :	World Health Organisation

Chapter One

Chapter One

Introduction to the Lake Cyohoha Sub-Basin

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1.0 Localisation and physical characteristics of Lake Cyohoha South

Lake Cyohoha South lies astride the borders of Rwanda and Burundi, two of the riparian states forming the Nile Basin Initiative (NBI) partnership. The trans-boundary Lake Cyohoha Sub-Basin is located between 29° 30' - 30° 30'East and 2° 10' – 2° 40'South at 1,400m – 1,600m above sea level. The basin is found between south-east of Rwanda and north-east of Burundi in an area locally known as Bugesera region.

The lake itself lies between latitude 2°20' - 2°35' South, and longitude 29°58' - 30°11' East at an altitude of 1,351m asl. Its is length about 200km. Part of its width of 0.4 – 1.8km covers a stretch of about 70km, becoming wider and deeper in the southern part up to width of 2.3km. It has a surface area of 78.5km2. The average depth is 7m and varies between 5 - 7m towards the north and 8 - 10m in the southern part. The bottom of the lake is sandy or gravely along the littoral zone, but the bottom is muddy (Ntakimazi, 1985).

Lake Cyohoha South is part of the Upper Kagera Lakes Complex and has numerous tributaries that feed into it. It lies in an area that is either part of or influenced by other significant wetlands or lakes including: -

- The Bugesera wetland area and Lake Cyohoha North which are located in the south central portion of Rwanda and lying between Lake Cyohoha North and Lake Cyohoha South (Figure 1.5). The former has since lost its open water and no longer exists as a lake. The MINETRE (2003) document suggests that floods in the valley depressions in the wet season caused siltation in Lake Cyohoha North. Increased agricultural practices both in the valley bottom and uphill and increased siltation could have been partly responsible for the death of Lake Cyohoha North.
- The Kanyaru Valley, located along the Burundi-Rwanda border and
- Lake Rwihinda in Burundi, located east of Lake Rwihinda Natural Reserve and adjacent to Lake Cyohoha South

The Bugesera region in Rwanda has nine lakes, namely Rweru, Cyohoha North, Cyohoha South, Gashanga, Kidogo, Rumira, Mirayi, Kirimbi and Gaharwa. On the Burundi side, the Bugesera area has four lakes, namely Cyohoha South, Gacamirinda, Rwihinda and Narungazi which constitute part of the Nile Basin system.

The Lake Cyohoha Sub-Basin is therefore a catchment of the Kagera Basin, a sub-basin of the River Nile which drains into Lake Victoria basin contributing about 34% of the total river inflow into Lake Victoria (Kagera River Basin Monograph/Database Team 2007).

1.1 Aspects of Climate

The climate of Lake Cyohoha South Sub-Basin can be explained using estimates of average monthly temperatures and rainfall were recorded at Murehe and Kirundo stations by the IGEBU over 25 years (1980 - 2004) (Nzigidahera et al., 2005). Of the 25 years, there are 12 years during which precipitation was lower than normal. And there are years (1984 -1985) when surplus rains where received. The years 1993, 1996 and 2000 were characterised by short rains.

1.1.1 Temperature

The area is characterised by a dry climate. The average atmospheric temperatures range between 21º C and 25º C. The average maximum temperature varies between 26 - 29° C. Diurnal temperatures, range between 13° C and 15.3 °C.

1.1.2 Winds

Strong wind velocity blows on Bugesera region (11 - 15 km/h) from the south-east towards north-west, especially in the afternoons.

1.1.3 Rainfall

The sub-basin receives about 900 mm of rainfall annually (ISAR report 1989). The distribution is due to parametres such as relief, altitude, availability of local natural resources (forests, wetlands, lakes). For example, Murehe station (figure 3.1) at an altitude of 1,564m, the annual average precipitations during the period 1973 to 1980 was 699 mm, with a minimum of 548mm in 1975, while in other parts of the basin, the average precipitation exceeded 1,000 mm (Ntakimazi, 1985).

In Kirundo (1,490m asl), just in the south-east of Lake Cyohoha, the average annual rainfall (1973-1980) was 998 mm, with a minimum of 590 mm in 1980. In 1981, precipitation of 1,183 mm (which had not been observed in the preceding eight years) was recorded in Kirundo (TABLE 1).

1.2 Geology

The geological nature of this sub-basin is dominated by the folded sediments of Precambrian Age consisting of successive layers of pelitic rocks, especially phyllite and the argillaceous schist, arenaceous rocks like the quartzose and quartzite. The granites and the granitogneissic rocks appear in the peneplane zones.

The catchment area which is also called Bugesera region is characterized by a central basin which is a granitic base surrounded by round hills with soft slopes and broader widened valleys. The most deeply dug valleys of the lower course of Akanyaru River pass through soils of sedimentary rocks with schistose predominance, while the rest of the basin is composed of granitic and gneissic nature. Around the central basin, the hilly zone is dominated in the west (left slope of Akanyaru) by a terrazzo-gneissic complex from where lies stem seams of quartzite. The south-east of the hilly zone is dominated by a quartzito-schistous unit, associated to quartzitic ridges.

1.3 Soils

The Bugesera region is characterised by two types of soils: the soils on hillsides that have long been exposed to degradation; and the soils in lowlands and valleys. The hillside soils consist of ferralsoils, more particularly xeroferralsoils. They are inert soils, exposed to erosion with a very thin humus-bearing layer. The lowlands soils are mostly alluvia in the bottoms of valleys, colluviums on the edges and the organic soils in the flooded zones.

The non-hydromorphic valleys are generally covered with vertisoils, characterized by a fine texture and composed of a sizeable quantity of clay and little organic matter. In the flooded valleys, including the bottom of the lakes, the organic soils are associated to silt and sand. Decomposition of biotic wastes, especially vegetation, is very slow in the muddy bottom of lakes and rivers, especially due to the acid pH and the anaerobic conditions. When accumulation of biotic wastes exceed decomposition rate, the result is a deposit of peat, with contents even more than 90% of organic matter.

TABLE 1.1: Variations of annual precipitations over the last 25 years in the area of Bugesera (data provided by the IGEBU, 2005)

Years	Variations	Annual precipitations (in mm)	Observations and conclusion
1980	-13,7%	923,3	Precipitations lower than normal rains
1981	11,7%	1197,2	Precipitations lower than normal rains
1982	5%	1130,5	Precipitations lower than normal rains
1983	-6,5%	1001,1	Precipitations lower than normal rains
1984	44,2%	1545	Precipitations higher than surplus rains
1985	20,7%	1292,9	Precipitations higher than surplus rains
1986	13,6%	1217,2	Precipitations lower than normal rains
1987	4%	1114,5	Precipitations lower than normal rains
1988	10%	1179,4	Precipitations lower than normal rains
1989	-8,4%	981,1	Precipitations lower than normal rains
1990	9,7%	1175,9	Precipitations lower than normal rains
1991	-6%	1006,1	Precipitations lower than normal rains
1992	-11,5%	947	Precipitations lower than normal rains
1993	-32,9%	718,2	Precipitation lower than rain overdrawn
1994	-14,3%	917,4	Precipitations lower than normal rains
1995	9,3%	1171,2	Precipitations lower than normal rains
1996	-26,4%	788	Precipitation lower than rain overdrawn
1997	14,8%	1230,3	Precipitations lower than normal rains
1998	12,8%	1209,2	Precipitations lower than normal rains
1999	-19,5%	861,3	Precipitations lower than normal rains
2000	-32,1%	726,9	Precipitation lower than, rain overdrawn
2001	-5,1%	1015,5	Precipitations lower than normal rains
2002	-1,8%	1051,8	Precipitations lower than normal rains
2003	5,6%	1131,9	Precipitations lower than normal rains
2004	0,02%	1073,9	Normal rains.

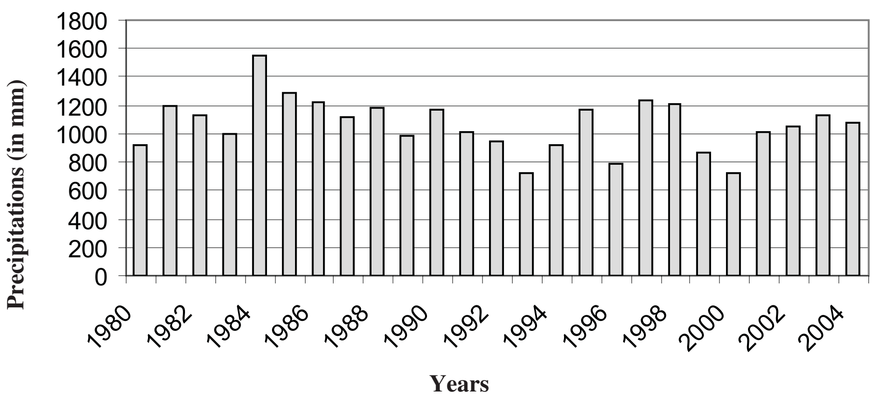

FIGURE 1.1: Annual precipitations (in mm)

FIGURES 1.1, 1.2, & 1.3) show that there has been a general reduction in annual precipitation while the temperatures have risen. Note that the 10-year period (**FIGURE**. 1.2) and the 25-year period (**FIGURE** 1.4), there was a marked reduction in amount of rainfall and a notable rise in annual temperatures.

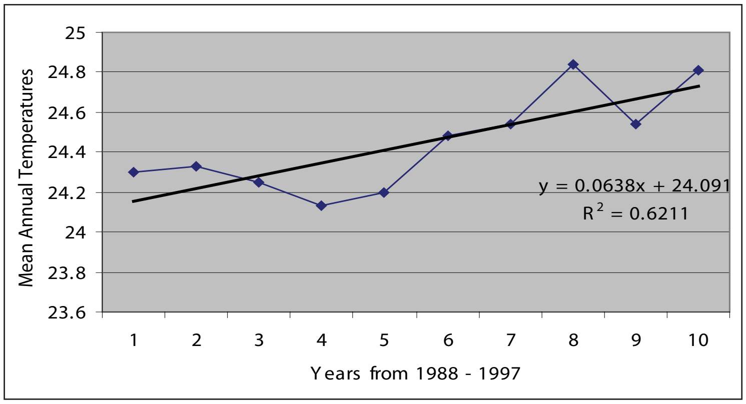

FIGURE 1.2: Temperature trends over a 10-year period (based on data from Appendix II of Ntakimazi *et al* (2000).

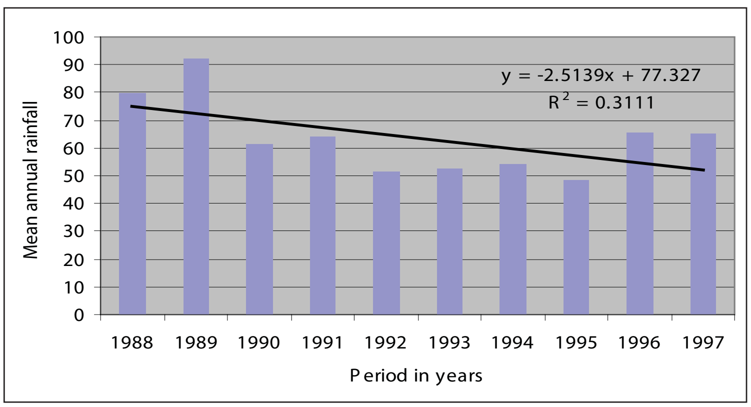

FIGURE 1.3: Rainfall trends over a 10-year period (based on data from Appendix II of Ntakimazi *et al* (2000).

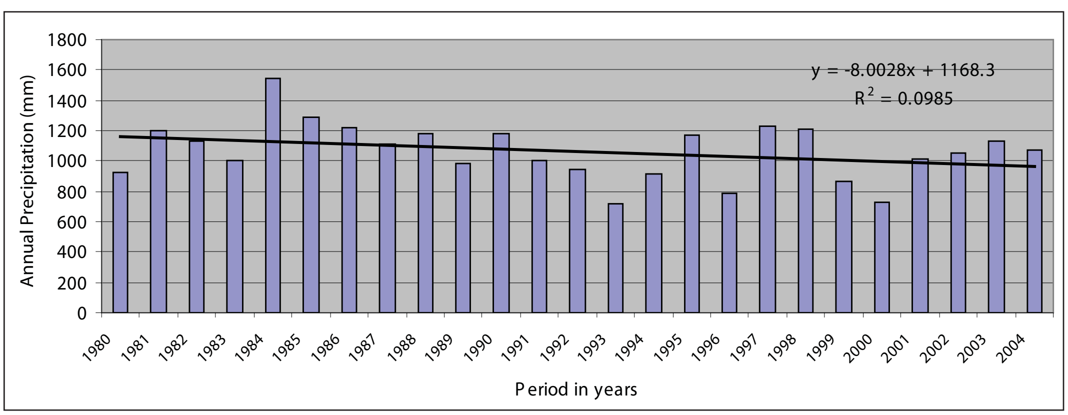

FIGURE 1.4: Annual rainfall trends in the Bugesera region over a period of 25-years (Graph is based on Data from Nzigidahera *et al* 2005).

Data used in **FIGURE**s 1.1 & 1.2 were obtained from Bujumbura Airport while that in **FIGURE** 1.4 was obtained from Bugesera region where Lake Cyohoha lies. Given the similarity in trends, it is assumed that Lake Cyohoha Sub-Basin region on both sides of the border share similar climatic conditions.

It may also be reasonable to make a connection between reduced rainfall amounts, increased temperatures, and reduced productivity in previously farmed uphill lands, increased population and increased demand for productive land. All together these factors could have contributed to the cultivation of the wetlands around Lake Cyohoha in both Burundi and Rwanda.

1.4 Hydrology and wetlands systems of Lake Cyohoha catchment

The Lake Cyohoha Sub-Basin has an interconnected system of *lacustrine, riverine* and *palustrine* wetlands which are an important source of livelihood (Bugesera House Survey, 2006) not only to the riparian communities but also many other communities in both Burundi and Rwanda, and the whole Nile Basin.

The sub-basin and its wetlands lie in the hydrological system of Bugesera region which consists of a network of three main sub-catchments namely; Akanyaru, Akagera and Nyabarongo – all found within the Nile Basin. In the west, Akanyaru constitutes the border between Rwanda and Burundi.

In the south there is Akagera River which also borders Rwanda and Burundi (**FIGURE** 1.5). The wetlands systems of Akanyaru are upstream while the complex system of Nyabarongo is downstream. Akagera River comes from the confluence of rivers Nyabarongo and Akanyaru and passes through different wetlands and connects to various lakes in Bugesera region of Rwanda and Burundi. When River Akagera floods during the rainy season around March to May, the water overflows and increases Lake Cyohoha's water level. The Bugesera lakes' water level is therefore mainly maintained by precipitations and feeds from wetlands.

Akanyaru and Nyabarongo rivers have known annual and inter-annual fluctuations of water which directly affects the lakes' water level. The annual fluctuations of water level in the lakes constitute an important modification in their limnological and bio-ecological parametres. Thus, the wetlands associated with Akanyaru and Nyabarongo-Akagera rivers play important functions in regulating water levels in lakes and rivers.

Akanyaru River flows in wetlands of *Cyperus papyrus* where it meanders and inter-connects with various lakes (Rwihinda, Cyohoha, Gacamirindi, Nagitamo, Mwungere and Narungazi). During the rainy period of April - May, there is more water in the Akanyaru and Nyabarongo rivers. Under these conditions, the surplus overflows the banks of the rivers and floods the wetlands causing the and the lakes levels to rise between 1.0m – 1.5m with extremes of up to 3.5m. The wetland systems store water during the rainy season and this is the one that replenishes the rivers during the dry season, making water available for a longer period to the natural and agricultural ecosystems.

At Lake Rweru (Figure 1.5) during the rainy season, the water level goes up causing a reverse flow into the Akagera which fills the lake and floods the entire wetland area. Even if the level in Nyabarongo is lower than that of the lake, there is no straight flow between the two, hence the flow runs towards Akagera due to the rise of water at the beginning of the rainy season. In March-April, the level of the river goes up more quickly and exceeds that of the lake; the flow is then reversed, and it is the river which runs towards the lake, flooding the entire surrounding wetlandy zone. With the fall, from June to August, the lake flows again towards Nyabarongo, initially over the wetland, by a single channel.

Lake Cyohoha is separated from Akanyaru River by an 11 metre deep wetland stretching 24kms long and 500m wide. The hydrological communication between the lake and the river is done by slow movement of the water through the wetlands depending on the seasonal precipitation. Therefore, the drainage of the wetlands of Akanyaru and Nyabarongo-Akagera complexes downstream would be fatal to the system as it can lead to reduction of the levels of the water going into Lake Cyohoha South and this could affect flow into the Nile system.

Lake Cyohoha South and its tributaries as natural water bodies constitute principal sources of water for domestic consumption, both for human and livestock. Despite the presence of such important water resources, water per capita uptake is less than five litres/person/day which is only a fifth of the recommended FAO/WHO per capita (MINITERE, 2004a).

PHOTO 1.1: Fetching water from Marembo in Busoni Commune (PHOTO: Fred Kiwazi)

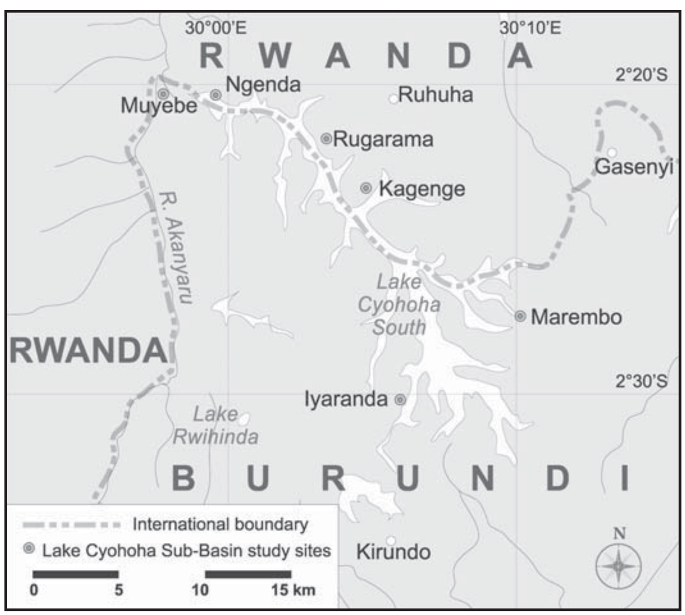

FIGURE 1.5: The Wetlands and Lakes of Bugesera and Gisaka (Akagera Basin)

Lakes :	1 : Gacamirinda	4 : Rumira	7 : Gaharwa
	2 : Gashanga	5 : Mirayi	8 : Birira
	3 : Kidogo	6 : Kilimbi	9 : Kanzigiri

PHOTO 1.2: Shoreline wetlands of Lake Cyohoha.

1.5 Terrestrial System

Surrounding the wetlands eco-systems, there are terrestrial areas (catchments*)* used for agriculture and are largely prone to soil erosion which threatens the existence of the Lake Cyohoha Sub-Basin due to siltation. The the terrestrial system observed are;

1.5.1 Forests/woodlands

Though referred to as a forest reserve, these areas are covered by thickets that dominate the trans-boundary Murehe Forest Reserve. The tree cover is scanty and the growing trees are suffocted by constant clearing due to agriculture.

1.5.2 Rangeland/pasture land

There are a few observable areas of rangelands that are used as pasture for livestock.

PHOTO 1.3: Representative terrestrial ecosystems of the sub-basin

1.6 Biological diversity of the sub-basin

Though species distribution tends to follow elevation and drainage, the biological diversity of the sub-basin is characteristic of the diversity of various sub-ecosystems. They include the savannah, woodlands, permanent and seasonal pulstrine, riverine and lacustrine wetlands as well as the euphotic and pelagic zones of the lake. Much of the sub-basin has been modified by human activities leading to serious impact on both aquatic and terrestrial sub-ecosystems. For example, *Lantana camara*, an invasive plant species, is common in the sub-basin.

The details of the biological diversity have been reasonably treated and reported in the subsequent chapters, with some highlights on vegetation and socio-economis as follows.

1.6.1 Vegetation

From the phyto-geographical point of view, Bugesera region is part of the eastern Sudano-Zambezian region. Flora species in this sub-basin presents many affinities with those of Kagera region and the district of Ankole in Uganda (Liben, 1960). In general, the principal ecosystem zones found in the Lake Cyohoha Sub-Basin are the dry lands composed of rangelands and savanna woodlands, characterised by short grasses, shrubs and small trees, commonly found in arid and semi-arid areas. In valleys, wetlands harbor water-tolerant vegetation which includes *Cyperus papyrus, Vossia cuspidata,* and *Phragmites species.*

Liben (1960) described flora species in the present Bugesera and gave a global view of the vegetation consisting of wetlandland species dominated by *Cyperus papyrus*. In the dry valleys, savannah species such as *Bothriochloa insculpta* and *Themeda triandra* are observed. In the north-eastern part of the region, the xeric zones are colonised savannah species such as *Loudetia simplex* and *Heteropogon contortus*.

The shrubby savannah of *Loudetia simplex* and *Pappea ugandensis*, the less xeric of Bugesera, was mentioned in the south-western part of the Lake Cyohoha Sub-Basin. Due to termite activities in some localised areas, savannah of *Loudetia simplex* and *Heteropogon contortus* became a xeric lawn of *Brachiaria dictyoneura* and *Brachiaria eminii* maintained by the overgrazing. The lawn of *Ctenium concinnum* and *Elyonurus argenteus*, the most xeric of Bugesera, was localised on lateritic lithosoils and the remains of the dismantled flagstones.

Concerning the heads of valleys and in recent colluviums, there was in general a timbered savannah of *Acacia seyal* and *Maximum panicum*. This type of vegetation occupied rather important surfaces in the hilly zones bordering Bugesera basin in the east where the relief supports an intense colluvial deposition. Timbered savannah of *Acacia nefasia* was localised on the humus-bearing alluvia in edges of the lakes. From the floristic point of view, the savannah was dominated either by *Acacia sieberiana*, *Acacia nefasia*, or by *Acacia caffra* var. *campylacantha*, or by a mixture of these two species with extremely similar ecological requirements. The xerophilous thickets are located on hillsides

1.7 Socio-economic environment

The population of Kagera Basin is reported to be highest in Burundi and Rwanda. Rwanda has a surface area of 26,338 km^2 and a population of 8,128,553 millions (MINECOFIN, Nov. 2003) with a natural growth rate of 3.1% (UNDP, Dec. 1997). Burundi has a surface area of 28,226 km^2 with a population density of 273 habitants/km$^{2.}$ According to the most recent census in Burundi (2005) and Rwanda (2003), the population density in the Lake Cyohoha Sub-Basin is evaluated at 205 habitats/km^2 (Bugesera), 289 (Busoni), 315 (Bugabira) and 449 (Kirundo). Areas like Ngeruka, Ruhuha and Nyarugenge, which surround the Cyohoha South lake, with brisk trans-boundary businesses have population densities between 345 and 400 habitats/km^2 (UNDP, GoR and UNEP 2007). This raises concern for the carrying capacity of this fragile ecosystem.

The UNEP June 2007 report showed that the mean estimated human population density was 248 peoples/km², which is eight times higher than that of 28 peoples/km² in Sub-Saharan Africa and that the difference was even getting bigger. Of all the Kagera Basin countries, the population density is reported to be highest in Burundi and Rwanda (two countries that share the highest population density in Africa). Such high population densities have serious and direct bearing on resource use and sustenance.

The main economic activity in Burundi and Rwanda is subsistance agriculture. The agricultural sector in Rwanda accounts for 91.1% of the active population and produces 43.5% of GDP and 80% of the country's exports, principally from coffee and tea (MINAGRI, 1998). The total surface area of arable land is 1,589,000 ha, or 60% of the national territory (National Land Policy, 2004). Most of wetlands have been heavily channeled and cultivated for food crops like paddy rice, maize, pumpkin, sweet potatoes, Irish potatoes and vegetables.

Lake Cyohoha South was a lucrative fishing ground in the 1950s and livelihood depended on fishing with occasional cultivation (UNDP *et al* 2007). Today, fishing activities are done on a part-time basis because fish stocks have gone down considerably.

Major impacts on the Cyohoha wetlands arise from agricultural practices and increasing demand for land for settlement and water. These human activities may encourage the survival of certain species of biodiversity while causing many others to disappear due to the human pressures and loss of habitat.

1.8 Conclusion

This Study was an initiative by the Nile Basin Transboundary Environment management project to highlight information of Wetlands and Biodiversity for a particular sites. The site was selected to provide in-depth baseline knowledge on what can be known about a particular site in view of the threats that are experienced in the Nile basin. But there are may other sites in the basin which have biodiversity which has never been described at all or has been adhocly studied. In order to manage the integrity of ecosystems it is necessary to know the interrelationships of the organisms and their environments and this has been well described in this report. The presence or absence of some organisms has direct influence on others. Many of the organisms are facing a serious problem of habitat loss and others contribute not only to livelihoods but can lead to poverty reduction through a number of ways of direct investment.

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Chapter Two

Chapter Two

Limnology of Lake Cyohoha Sub-Basin

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Introduction

Over a forty-year period, there have been a lot of changes in the Lake Cyohoha South Sub-Basin including loss of natural vegetation and arable soil due to human population pressure. The result is that the changes have caused effects to aquatic ecosystems and their biodiversity, with induced changes in limnological parametres as well as disequilibrium in biotic communities.

The management and development of Lake Cyohoha South Sub-Basin through wise use of its natural water resources, wetlands areas and biodiversity require supportive basic scientific information on its status. This study presents basic information to support sustainable development.

This integrated study which involved consultations with stakeholders has examined the current livelihood opportunities and risks related to utilisation of Lake Cyohoha Sub-Basin water resources.

2.1. Methods used

Literature review enabled compilation of accessible knowledge and information on water quality parametres. Visits to training and research institutions as well as to some public and private organisations in Burundi and Rwanda were done.

Sampling for ground truthing was done by taking representative water samples from the lake basin for the study of limnological parameters. The following sampling sites were selected as indicated in Figure 2.1.

- The pelagic zone of Lake Cyohoha towards the River Akanyaru and associated extensive wetlandland (Murambi site);
- The pelagic zone of a mid-section in the Lake Cyohoha South (Bihari site);
- The southern section of Lake Cyohoha South (Rutonde site);
- Two sites on Akagera River, namely Kumugorore and Kirambizi.

Concerning microbiological study, five stations were selected and sampled on January 22, 2008, namely Gakoni I, Gakoni II, Rubona and Rugarama on the Rwandan side as well as Kayanza on Burundian side as indicated in TABLE 2.1,

TABLE 2.1: **Sampling Sites on Lake Cyohoha South and its adjacent areas**

Sampling Sites	Altitude	Geographical position
Site A : Murambi	1,345m	Sud 02° 20' 581" Est 29° 59' 834"
Site B : Bihari Site C : Rutonde	1,349m 1,351m	Sud 02° 20' 642" Est 30° 00' 966" Sud 02° 21' 230" Est 30° 02' 221"
Site D : Akanyaru River (Kumugorore Site I)	1,352m	Sud 02° 19' 418" Est 029° 57' 724"
Site E : Akanyaru River (Kirambizi Site II)	1,356m	Sud 02° 19' 524" Est 029° 57' 646'

FIGURE 2.1: **Map of Lake Cyohoha South with selected limnology sampling sites**

2.2. Description of field methods

2.2.1. Physical-chemical parametres

The following parameters were analysed on site in the field as follows;

a) Dissolved oxygen, electric conductivity, pH and temperature profile were recorded automatically, at different depths, using Hydrolab and/or a Multiline-F set WTW)

b) An automatic turbid metre was used to quantify water turbidity in (Nephelometre turbidity Unit (NTU)

c) Ammonia (NH4+) was determined using **PHOTO**metric method described by Descy (1989).

d) Nitrites was determinied using Sulfanilic Acid method coupled with colourimetric dosage.

e) Nitrates was determinied using chromotropic acid method (West & Ramachandran (1966) adapted by Descy (1989)

f) Total phosphorus as well as ortho-phosphates were analysed using colourimetric method where optical density would be determined by spectro**PHOTO**metric method.

g) Total Nitrogen was determined using KJELDHAL method as indicated in Standard methods (A.P.H.A, 1985).

2.2.2. *Chlorophyll "a" and Primary production*

Phytoplankton biomass is usually measured by chlorophyll « a » concentration. A given water volume was filtered using fibre glass filter to retain planktonic algae. The filter was then immersed in 90% acetone solvent for 24 hours at 4°c. The acetone extracts algae chlorophll « a » which is determined using spectrophotometre at 665nm absorbance before and after extract acidification by Hcl 0.1 N. The chlorophyll concentration is calculated as following:

$$\text{Chl. « a » } (\mu\text{ g/l}) = \frac{11.9 \times 2.43\ (Db-Da)}{V} \times \frac{v}{1}$$

Db: density before; Da: Density after;
V: filtered volume; v: solvent volume (acetone); 1 : optical length course

Primary production was determined using gas exchange due to photosynthesis. This involved direct measurement of oxygen produced during light phase or direct assimilation of carbondioxide during dark phase following methods used by Mukankomeje (1992) and A. Dauta & J. Caplanq (1999).

2.2.3. *Zooplankton*

The density of each zooplankton species (Number of individual per cubic metre of water) was calculated using the following formula:

$$Aa = (Xa+Ya+Za) \times V/v$$
$$B = (d/2) \times (d/2) \times 3.1416 \times H$$
$$Da\ (N/m3) = Aa / B$$

Aa = total number of species « a » in the sample.
Xa = total number of species « a » counted in the first sub-sample
Ya = total number of species « a » counted in the second sub-sample.
Za = total number of species « a » counted in the third sub-sample
V (ml) = volume of concentrated sample from which we deducted sub-samples
v (ml) = volume of sub-sample (0,5 ; 1,0 or 2ml) which depends to the abundance of zooplankton
B (m3) = the volume of water collected from the lake using sample bottle or plankton net.
d (m) = the diametre of plankton net mouth
H(m) = the distance or depth from which the plankton net has been lifted
Da (N/m3) = density of species « a » estimated from the determined sample.

2.2.4. Bacteriological analysis

Bacterial studies were carried out using bacteriological set equipment that included Autoclave, Incubators 44°C and 37°C, Manifold holders vaccum, Filtration apparatus, Water bath, Culture medium bottles and Culture medium. The following coliforms were determined from 100ml samples of water;

a) Faecal coliforms

b) Total coliforms

2.3 Results

2.3.1. Physico-chemical parametres of Lake Cyohoha and its tributaries

Nine physico-chemical parametres were considered for water quality studies and these are summarized in the TABLES 2.2 and 2.3.

TABLE 2.2: Physic-chemical parametres of Lake Cyohoha South and Akanyaru River

Site	**Max Depth** (m)	**Transparency Secchi** (cm)	T° (°C)	pH	D.O (mg O_2/l)	Conductivity (µS/cm)	Turbidity (NTU)
MURAMBI	2.5	52					
- 0m			25	7.28	8.5	665	13.1
- 2.0m			25.1	7.19	7.90	666	15.0
BIHARI	4.0	42					
- 0m			25.5	6.91	8.67	662	14.1
- 3.0m			24.4	6.91	4.64	665	16.2
RUTONDE	4.5	41					
- 0m			25.9	7.78	8.19	659	-
- 2m			25.3	7.02	7.65	661	-
- 4m			24.4	6.48	6.43	662	-
AKANYARU Site I (Kumugorore)	5.4	5	23.1	6.54	2.9	98.2	571
AKANYARU Site II Kirambizi	9.3	4.8	23.1	6.41	2.9	98.9	598

Maximum water depth of Lake Cyohoha South in the selected sites ranged between 2.5 - 4.5 metres. This is lower that the water depth of 7 metres reported by Ntakimazi (1985). Akanyaru River is narrow in width but still recorded a maximum depth of 9.3m.

Bugesera region in which Lake Cyohoha South is situated experiences a high solar radiation (2608.3x104 j/m2/d) and strong winds (11 - 15 km/h) from south-east in the afternoon (Burgis & Symeons, 1987).

Secchi Transparency values ranged between 0.40 - 0.50 metres in all sampled sites. This is lower than the recorded water transparency values of 0.8m (Ntakimazi, 1985) and 0.7 - 0.8 metres (Burgis, 1987). This indicates that over a period of twenty years, the Secchi transparency in Lake Cyohoha South has decreased. The turbidity in Akanyaru River is high about 585 NTU and is a consequence of the low Secchi transparency.

Minor temperature stratification were noticed, especially in Bihari and Rutonde sites where measurement was carried out before noon. In the afternoons, the lake probably mixes due to winds usually blowing from south-east to north-west. However, the average temperature was 25°C as mentioned in previous works (Reizer, 1977; Ntakimazi, 1985), although a was a little lower in Akanyaru River.

The pH in Bihari was recorded as 6.9 while in sites like Rutonde it was 7.7. The pH values were a little higher in upper layers (minor stratification) probably due to Photosynthesis activity daytime. Akanyaru River was recorded acidic probably because of the presence of a wetland (see Table 2.2) .

The conductivity is a good indicator of ions concentration in a lake, favourable for a consideration of water body productivity. In all sites and at different depths, except Akanyaru, conductivity measured high values around 665 µS/cm. This figure is three times more than earlier recorded by Ntakimazi in 1985 (199 and 214 µS/cm respectively in littoral and pelagic zones).

Dissolved oxygen stratification was noticed in all sites. Values were high at about 8.67 mg/l in the surface water of Lake Cyohoha South.

2.3.2. Nutrients

Dissolved parametres are mostly responsible for the development of all aquatic biotic organisms. Nevertheless, high concentration of some elements such as Ammonia and Nitrites may contribute to aquatic ecosystem disequilibrium and affect distribution of biotic species.

TABLE 2.3: Nutrients in Lake Cyohoha South (November 2007)

Sampling Site	Depth	$N\text{-}NO_3^-$ mg/l	**$N\text{-}NO_2^-$ mg/l**	**$N\text{-}NH_4^+$ mg/l**	**$P\text{-}PO_4^{3+}$ mg/l**
Murambi	0m	0.049	0.047	0.104	0.081
	1.5m	0.034	0.188	0.170	0.082
Buhari	0m	0.071	0.097	0.094	-
	1.5m	0.024	0.053	0.067	0.231
	3m	0.060	0.066	0.125	0.212
Rutonde	0m	0.011	0.031	0.062	0.207
	1.5m	0.017	0.022	0.399	0.222
	3m	0.033	0.038	0.394	0.067
Akanyaru I	5.4m	1.150	0.015	6.000	0.850
Akanyaru II	9.3m	1.230	0.015	6.300	0.450

Ammonium ion ($N\text{-}NH_4$+)

Ammonium ion and Nitrates are the Nitrogen principal forms usually found and utilised by biotic organisms in aquatic ecosystem. Ammonium ion values ranged between 0.062 and 0.399 mg/l in all selected sites, with high values in deeper zones, especially in Rutonde site.

Nitrites ($N\text{-}NO_2^-$)

In Lake Cyohoha South, results from water analysis showed lower concentrations of nitrites (0.022 to 0.188 mg/l $N\text{-}NO_2^-$) in all selected sites. At Murambi site (Table 2.3), just located within the wetland area, a deep layer of vegetation detritus which is still in decomposition phase, and nitrites values were a little bit higher. The nitrites toxicity limits fish and other aquatic organisms if it rises up to 0.2 mg/l.

Nitrates ($N\text{-}NO_3^-$)

Lower concentrations of values of Nitrates were recorded in Lake Cyohoha South (0.011 to 0.071 mg/l $N\text{-}NO_3^-$) in all selected sites. The nitrates values which are less than 10 mg/l are favorable for the development of biotic organisms in aquatic ecosystems.

Phosphates or Ortho-phosphates

Ortho-phosphates nutrients usually constitute the most limiting factor for the development of primary production (phytoplankton) and are responsible for aquatic ecosystem eutrophication.

In Lake Cyohoha South, results from water analysis collected at the surface and in deeper areas showed ortho-phosphates values ranged between 0.067 and 0.231 mg/l. The ortho-phosphates values were significantly higher than those observed in Lake Muhazi by Mukankomeje (1992) and Kilham (1969). Ntakimazi (1985) also reported that ortho-phosphates values common to all sub–regional lakes ranged between 0.01 – 0.02 mg/l (Table 2.4).

Compared to Lake Cyohoha South, Akanyaru River showed higher concentrations of nitrites out of the nutrients. Weathering rocks, cropping systems and decomposed organic matters in watershed areas provide the river considerable mineral salts which are not utilised by non existent Photosynthetic flora, so that higher values nutrients concentrations were found.

TABLE 2.4: Changes with time in physic-chemical parameters of Lake Cyohoha South

Date	Depth	T°C	Transpar. Secchi(m)	pH	Conductivity (µs/cm)	SO_4^{2-} (mg/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	NO_2^-	PO_4^{3-}	Reference
1969	-	23	0.8	7.2	210	1.1	-	1.3	-	-	Kilham (1969)
1977	-	27	1.4	8.9	335	8.2	1.1	-	-	-	Reizer (1977)
1981	7	25.5	0.8	7.7	211	5.2	0.20	0.16	-	0.03	Ntakimazi (1985)
2007	4.5	25.1	0.45	7.1	663	-	0.18	0.04	0.07	0.16	Gashagaza(2007)

2.4. Plankton study

Lake Cyohoha primary production evaluation Chlorophylle ''a''

TABLE 2.5 shows Chlorophyll ''a'' concentrations at two levels (surface and near bottom). Chlorophyll ''a'' values varied between 9.70 and 43.30 µg/l. Chlorophyll '' a'' concentrations fluctuated within the same depth level depending to site selected and sampling time.

TABLE 2.5: Chlorophyll '' a'' concentrations in Lake Cyohoha South (November 2007)

		Murambi Chl-a (µg/l)	Bihari Chl-a (µg/l)	Rutonde Chl-a (µg/l)
27-Nov	Surf	28.383	15.08	
	Fond	9.744	33.026	
28-Nov	Surf	9.704	43.306	12.373
	Fond	24.824	12.528	24.128

In general, Chlorophyll ‘’a” concentrations varied between 9.7 to 43.3 µg/l.

High concentration of Chlorophyll ‘’a” was observed in surface water layers at Murambi on November 28, 2007 while Bihari had high concentration of Chlorophyll ‘’a” in surface water layers on the previous day November 27. It is known, that the maximum concentration of Chlorophyll ‘’a” is correlated to maximum phytoplankton biomass concentration, and also that daily migration of phytoplankton species at different depths in water column is reported in different water bodies, seeking optimum conditions within photic zones to accomplish their metabolic activities.

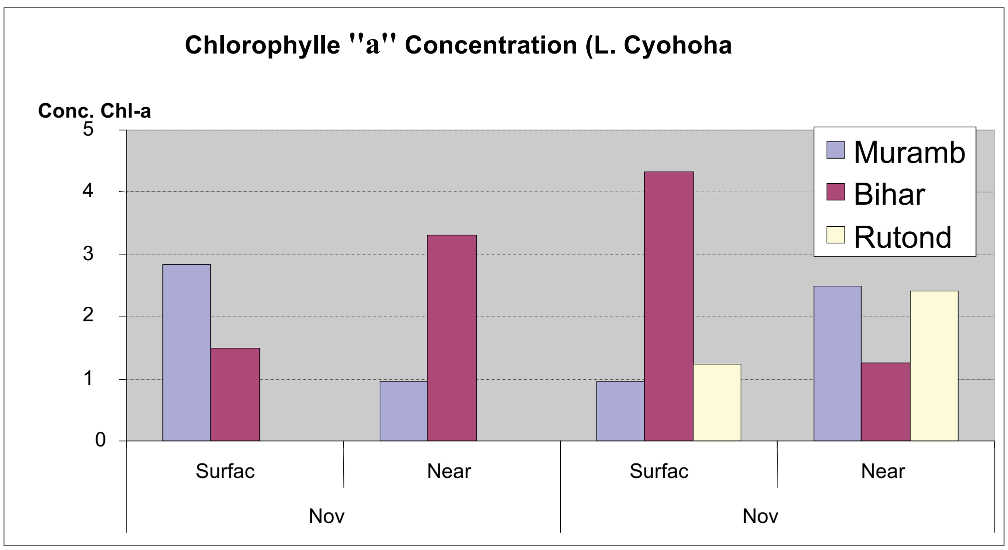

FIGURE 2.2: Chlorophyll ‘’a” concentration

Primary production

Appendix 2.2a, 2.2b and 2.2c show results of primary production in Lake Cyohoha South. From the tables, the photic zones for intensive photosynthesis activity are found at 1.25m, 1.08m and 0.98m depth respectively at Murambi, Bihari and Rutonde sites. In the same line, Photosynthetic productions and their variation with depth are presented in those tables and illustrated at **FIGURE** 2.3 respectively for Murambi, Bihari and Rutonde sites.

Maximum primary production (Pmax)

The maximum primary production was deduced from the net photosynthesis curve at a specific depth (**FIGURE** 2.3). For Lake Cyohoha South, maximum primary production varied as follows: 0.18 mgO2/l/h at Murambi, 0.59 mgO2/l/h at Bihari and 0.57 mgO2/l/h at Rutonde. The values obtained were in the same range as those reported by Mukankomeje

(1992) for Lake Muhazi (0.7 à 1.21 mgO2/l/h). The two lakes are shallow and reached the eutrophic stage.

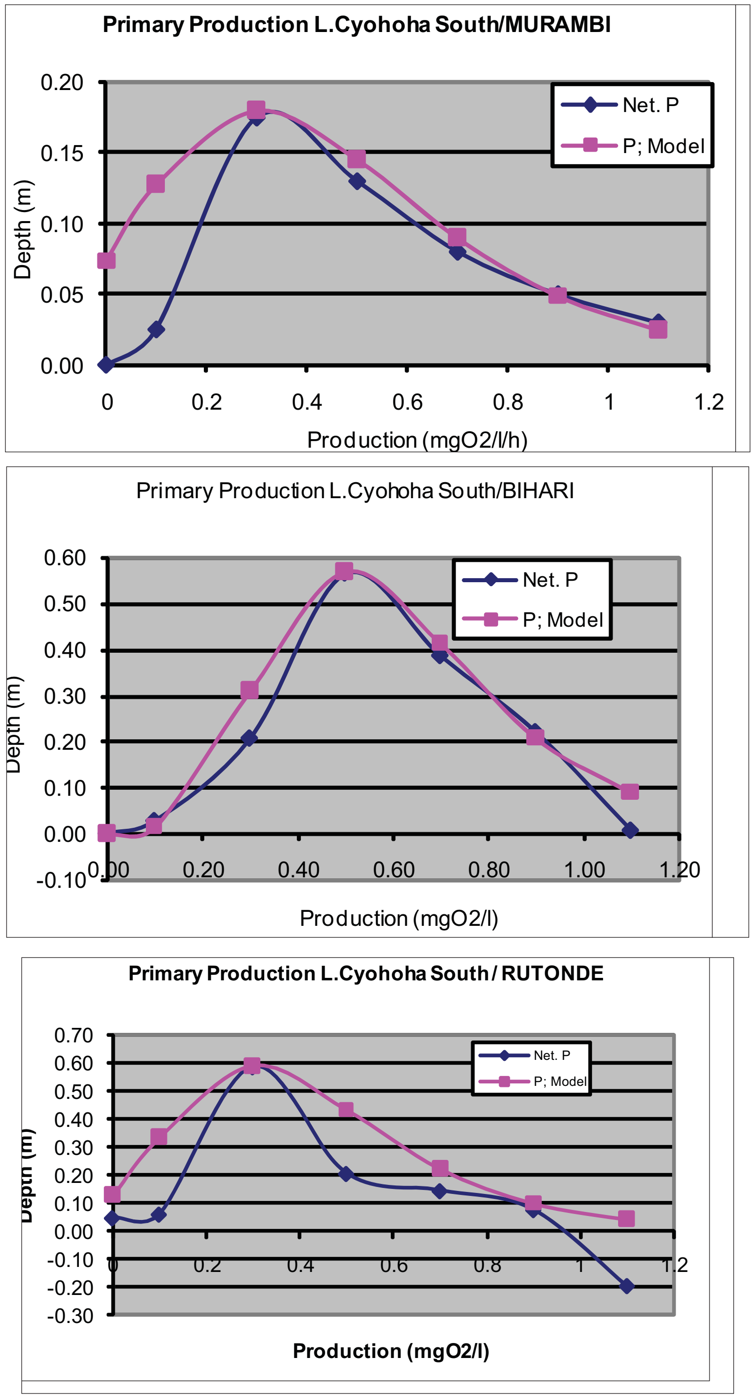

FIGURE 2.3: **Variation of net primary production and photosynthetic production in relation with Water Depth in Murambi, Bihari and Rutonde sites (Lake Cyohoha South).**

Daily primary production

The daily primary production expressed in mgC/m3 was calculated through the photosynthesis simulation programme which utilises all photosynthesis parametres (sampling time, light, incubation period and duration, Chlorophyll "a" concentration rate, Secchi transparency and maximum depth of the site). For more precision, see **Appendix** 2.1.

Lake Cyohoha South's daily primary production was found to be 14.0 mgC/m3/d, 19.39 mgC/m3/d and 92.04 mgC/m3/d respectively for Murambi, Bihari and Rutonde. These productions are equal in surface unity as 34.0 mgC/m2/d, 79.51 mgC/m2/d and 414.2 mgC/m2/d respectively for the three sites. Rutonde site which is a truly pelagic zone and doesn't receive any influence from littoral area has the higher daily primary production.

Differences recognised in daily primary production from site to site might be attributed to differences in phytoplankton biomasses within sites, but also to ecological factors which are used in simulation model.

2.5. Zooplankton study

TABLE 2.6. Zooplankton species distribution by site

Taxonomic level	CYOHOHA-SOUTH		
	Site 1: Bihari	Site 2: Murambi	Site 3: Rutonde
COPEPODES	+	+	+
Thermocyclops	+	+	+
Mesocyclops	+	+	+
Tropocyclops	-	-	+
CLADOCERES	-	+	-
Diaphanosoma	-	-	-
Moina	-	+	-
Alona	-	-	-
ROTIFERES	+	+	+
Anuraeopsis fissa	-	-	-
Asplachna	-	-	-
Bdélloïdes	-	-	-
Brachionus calyciflorus	+	+	+
Brachionus caudatus	-	+	-
Brachionus falcatus	-	-	-
Hexarthra	-	-	-
Colurella	-	-	-
Keratella tropica	-	+	+
Polyarhtra	-	-	-
Lecane	-	-	-
Tricocerca	-	-	-
Ploesoma	+	+	-

+ = present, - = expected but not recorded

TABLE 2.7 Zooplankton Abundance in Lake Cyohoha South (Density in individual Number /m3)

Taxa	Lake Cyohoha South					
	BIHARI		MURAMBI		RUTONDE	
	Density (ind/m^3)	%	Density (ind/m^3)	%	Density (ind/m^3)	%
COPEPODA	21935	95,4	14650	85,1	16255	94,4
Nauplii	1262	5,8	3898	26,6	4815	29,6
Copépodites	8347	38,1	7032	48,0	6573	40,4
Thermocyclops	12181	55,5	3363	23,0	4586	28,2
Mesocyclops	146	0,7	357	2,4	76	0,5
Tropocyclops	0	0,0	0	0,0	204	1,3
CLADOCERA	0	0,0	25	0,1	0	0,0
Diaphanosoma sp	0	0,0	0	0,0	0	0,0
Moina sp	0	0,0	25	100,0	0	0,0
Alona sp	**0**	**0,0**	**0**	0,0	**0**	**0,0**
ROTIFERA	1068	4,6	2548	14,8	968	5,6
Anuraeopsis fissa	0	0,0	0	0,0	0	0,0
Asplachna sp	0	0,0	0	0,0	0	0,0
Bdélloïdes	0	0,0	0	0,0	0	0,0
Brachionus calyciflorus	874	81,8	713	28,0	866	89,5
Brachionus caudatus	0	0,0	102	4,0	0	0,0
Brachionus falcatus	0	0,0	0	0,0	0	0,0
Hexarthra sp	0	0,0	0	0,0	0	0,0
Colurella sp	0	0,0	0	0,0	0	0,0
Keratella tropica	0	0,0	51	2,0	102	10,5
Polyarhtra sp	0	0,0	0	0,0	0	0,0
Lecane sp	0	0,0	0	0,0	**0**	0,0
Tricocerca sp	0	0,0	**0**	0,0	**0**	0,0
Ploesoma sp	194	18,2	1682	66,0	0	0,0
TOTAL	23003	100	17223	100	17223	100

0 = Expected but was not recorded.

Like in many other fresh water habitats, three groups of zooplanktons were observed in Lake Cyohoha South, namely Copepods, Cladocera and Rotifers. The Copepod group dominated others with more than 90 percent relative abundance. Cladocera and Rotifers groups were scarce in species composition and density. Genus *Thermocyclops*, cyclopoïdites of 0.6 – 0.8 mm dominated the Copepods, while only one species of Cladocera and two species of Rotifers were observed (Table 2.6 and 2.6).

2.6. Microbiological study

Tables 2.8 to 2.12 show analysis of microbiological studies at four sites in the sub-basin. In all the sites, there is some level of contamination that was observed.

TABLE 2.8: Sampling site: Lake Cyohoha South / Gakoni I

Thermotolerant (faecal) coliforms	Culture Medium	Results
Total Coliforms à 37°C during 24H	Lauryl Sulfate Broth	> 1 x 10^5 cfu/100ml
Faecal Coliforms à 44°C during 24H	Lauryl Sulfate Broth	3 x 10^4 cfu/100ml
Escherichia Coli à 44°C during 24H	m Coliblue	Absent
Faecal Streptocoques à 37°C pdt 24H	Slanetz agar	
Aureus Staphylocoques à 37°C during 24H	Mannitol Salt Agar	4 x 10^4 cfu/100ml
Anaerobies Sulfito Reducters 37° C during 24h / 20ml ISO 6461-2	SPS	1 x 10^1 cfu/100ml

TABLE 2.9: Sampling site: Lake Cyohoha South / Gakoni II

Thermotolerant (faecal) coliforms	Culture Medium	Results
Total Coliforms à 37°C during 24H	Lauryl Sulfate Broth	1 x 10^4 cfu/100ml
Faecal Coliforms à 44°C during 24H	Lauryl Sulfate Broth	1 x 10^3 cfu/100ml
Escherichia Coli à 44°C during 24H	m Coliblue	Absent
Faecal Streptocoques à 37°C pdt 24H	Slanetz agar	
Aureus Staphylocoques à 37°C during 24H	Mannitol Salt Agar	4 x 10^4 cfu/100ml
Anaerobies Sulfito Reducters 37° C during 24h / 20ml ISO 6461-2	SPS	<1 x 10^0 cfu/100ml

TABLE 2.10: Sampling site: Lake Cyohoha South / Rubona

Thermotolerant (faecal) coliforms	Culture Medium	Results
Total Coliforms à 37°C during 24H	Lauryl Sulfate Broth	>1 x 10^5 cfu/100ml
Faecal Coliforms à 44°C during 24H	Lauryl Sulfate Broth	7 x 10^4 cfu/100ml
Escherichia Coli à 44°C during 24H	m Coliblue	Présent
Faecal Streptocoques à 37°C pdt 24H	Slanetz agar	
Aureus Staphylocoques à 37°C during 24H	Mannitol Salt Agar	>1 x 10^4 cfu/100ml
Anaerobies Sulfito Reducters 37° C during 24h / 20ml ISO 6461-2	SPS	

TABLE 2.11: Sampling site: Lake Cyohoha South / Rugarama

Thermotolerant (faecal) coliforms	Culture Medium	Results
Total Coliforms à 37°C during 24H	Lauryl Sulfate Broth	8 x 10^4 cfu/100ml
Faecal Coliforms à 44°C during 24H	Lauryl Sulfate Broth	9 x 10^3 cfu/100ml
Escherichia Coli à 44°C during 24H	m Coliblue	Absent
Faecal Streptocoques à 37°C pdt 24H	Slanetz agar	
Aureus Staphylocoques à 37°C during 24H	Mannitol Salt Agar	6 x 10^3 cfu/100ml
Anaerobies Sulfito Reducters 37° C during 24h / 20ml ISO 6461-2	SPS	Absent

TABLE 2.12: Sampling site: Lake Cyohoha South / Kayanza/ BURUNDI

Thermotolerant (faecal) coliforms	Culture Medium	Results
Total Coliforms à 37°C during 24H	Lauryl Sulfate Broth	4 x 10^4 cfu/100ml
Faecal Coliforms à 44°C during 24H	Lauryl Sulfate Broth	1x 10^3 cfu/100ml
Escherichia Coli à 44°C during 24H	m Coliblue	Absent
Faecal Streptocoques à 37°C pdt 24H	Slanetz agar	
Aureus Staphylocoques à 37°C during 24H	Mannitol Salt Agar	4 x 10^2 cfu/100ml
Anaerobies Sulfito Reducters 37° C during 24h / 20ml ISO 6461-2	SPS	Absent

Discussion

Over a period of the past forty years, there are noticeable changes in the water quality of the lake and its basin, including loss of natural vegetation. This may be due to human activities, mainly agriculture and livestock.

Lake Cyohoha South's limnological parametres indicate that over time, the water depth has decreased from 7 metres measured 27 years ago (Ntakimazi, 1985) to 4.5 metres measured during this study. The decrease in water depth may be due to sediments deposit into the bottom of the lake from watershed erosion resulting from poor catchment management practices.

The water Secchi transparency decreased threefold from 1.4 metres to 0.45 metres! Two reasons explain this decrease: water turbidity increased up to 16.2 NTU in Murambi site for example, but also growing primary and secondary productions biomasses capable of using considerable mineral salts and organic nutrients released into the lake, form a barrier to solar radiation. Furthermore, strong winds blowing in the afternoon turn over water columns and bring up deposited sediments from bottom to surface water layers. The Akanyaru River transports soil sediments by rain from the hillsides and these often change the water colour and drastically increase turbidity up to 585 NTU, which contributes to the drop in water Secchi transparency.

Lake Cyohoha South is a shallow aquatic ecosystem. It is stratified in the morning and experiences turn over and mixing water in the afternoon. Minor stratified temperature observed is due to influence of air temperature and particularly direct solar radiations in upper water layers. In the lake as well as in Akanyaru River, the temperature favours presence of biotic organisms.

Minor stratification of pH values were observed in all stations. Higher values of pH in water surface layers might be due to photosynthesis activity during daytime, while lower pH values in Hypolimnion zones might be due to the decomposition process of accumulated organic matters which produce humic acids, consequently decreasing the pH. The presence of papyrus vegetation around the lake in the North Bay and all alongside Akanyaru River might have released humic acids into the lake which contributes to decreasing pH in below the surface.

The high dissolved oxygen concentrations were found in middle water columns and at surface layers. This is favourable for development of biological productivity in the lake. The decomposition of accumulated organic sediments in benthic zones consumes oxygen so that concentrations of this gas decreased near bottom areas.

The conductivity in Lake Cyohoha South increased threefold from 210 μS/cm up to 663 μS/cm since it was last recorded thirty years ago. This is mainly due to human activity in the catchment. Cyohoha South is a polymictic lake, meaning it mixes frequently which is favourable for nutrients cycling in all water layers.

Compared to the neighbouring Lake Rweru, Cyohoha South is richer in mineral salts. Lake Rweru is surrounded by massive wetland of papyrus vegetation which retains synthesised mineral salts and organic compounds and before water is released into the lake (Gaudet, 1977 and Ntakimazi, 1985). Mukankomeje (1992), Viner (1975), Gaudet (1977), Kilham (1969), Kiss (1976) also report that mineral salts are found in most regional aquatic ecosystems as traces while some high mineral salts concentrations are found in the lakes.

Several authors reported that ammonium ion constituted the most frequent nitrogen form found in Lake Muhazi (Mukankomeje, 1992) and other eastern Rwanda lakes (Burgis & Symoens, 1987). Ammonium ion concentrations were also found to be more frequent than other nutrients in Lake Cyohoha South.

Usually, as noticed also in Lake Cyohoha South, it is in deeper zones of aquatic ecosystems where bacteria decompose organic matter and produce a lot of ammonium ion. In the afternoon, when strong wind blows the lake and permits nutrients recycling in all water layers, ammonium ion reaches the upper photic zones. Concentrations of ammonium ion of over 1.2 mg/l are known to be dangerous and harmful to biotic organisms.

Concerning the analysis of mineral salts in Lake Cyohoha South, Kiss (1976) and Karangwa (1982) in Burgis & Symeons (1987) gave the following concentrations: Calcium (9.0 mg/l), Magnesium (10.85mg/l), Sodium (25.75 mg/l), Potassium (9.55 mg/l) and Chlore (4.30 mg/l).

The above mineral salts concentrations were significantly higher than those found in Lake Ihema (in Rwanda). Calcium values varied between 2.4 and 5mg/l at surface area, magnesium from 5.4 to 5.9 mg/l and potassium with trace values of 0 to 3.2mg/l. The reason why Cyohoha South has higher mineral salts concentrations than Ihema is that the surrounding areas of the lake have been intensively exploited for agriculture activities, targeting the Akanyaru wetland which would be filtering mineral brought by rain water. In contrast, because Lake Ihema is situated within a national park, it is protected with limited human activity.

In general, nitrogen and phosphorus compounds in Lake Cyohoha South were higher than reported in other eastern lakes. This implies that Lake Cyohoha South in an eutrophic lake. It also has considerable biomass of photosynthetic flora which consumes available nutrients. The worry with increasing nutrients coupled with the continued sedimentation is that it may lead to encroachment of terrestrial plants and this might lead to the disappearance of the lake.

Although the nutrients found in Lake Cyohoha South can potentially support a good primary biological productivity in this aquatic ecosystem, efforts should be made to avoid excessive input of nutrients. Considering concentrations of nitrogen and phosphorus compounds found in the lake, this aquatic ecosystem can be categorised among eutrophic lakes.

The high recorded primary production values (Figure 2.2) shows that considerable phytoplankton biomass is available in the lake and is capable of supporting important micro-phytoplanktivorous fish species. The fish production biomass capable of consuming the important phytoplankton biomass has severely decreased (Ntakimazi, Chapter 5 of this report)so appropriate measures should be considered to avoid lake eutrophisation.

Cyclopoïdes dominated other zooplankton groups with density of 15 to 22 individuals/litre which was relatively lower than other lakes such as Muhazi (955 individuals/litre) and Mugesera (843 individuals/litre). Ntakimazi (1985) reported also that zooplankton in Lake Cyohoha had low relative density of 3 to 181 individuals/litre.

Ideally, *Thermocyclops* Copepod species feed on blue-green algae including filamentous forms and *Microcystis* colonies which are abundant in Lake Cyohoha South (Moriarty *et al,* 1973). This indicates that zooplankton feeding in the lake is very important to for the development of a part of secondary production in that lake. Nevertheless, according to Moriarty *et al* (1973), large phytoplankton which dominates Lake Cyohoha South, might constitute a limiting factor as feed for early stages (nauplii and copepodites) of copepod and consequently affect their development.

Feeds limitation might constitute a limiting factor for the development of another group of zooplankton in the Cladocera species, because as filters they are unable to consume phytoplankton dominated by the blue-greens group present in Lake Cyohoha South. Furthermore, lower oxygen concentrations or anoxic zones available in hypolimnion might also constitute a limiting factor for the development of Cladocera species and nauplii of Cyclopoïdes.

From the side of bacterial analysis, water sampled from five stations in Lake Cyohoha South contained bacterial harm germs, especially in Rubona where *Escherichia Coli* was present. This implies that the use of the lake water for domestic consummation should be preceded by boiling it and in some cases, such as the water collected from Rubona site, chemical treatment should be considered (IEA Household Survey 2006, MoH Epidemiological record 2006).

Policy, Legal and Institutional Framework

2.7. Environment policy

Both Rwanda and Burundi have environment policies. There is need to strengthen the coordination framework to manage the multiple interests related to land and water resource. Management of wetland resources is embedded in general policies on environment and this requires to address the interventions on key issues of their degradation to conserve the main water bodies, inducing monitoring the limnological parametres.

In Rwanda, the overall objective of the National Environment Policy is the improvement of man's well-being, the judicious utilisation of natural resources, protection and rational management of ecosystems for sustainable and fair development. As the country is facing enormous number of problems in environmental resources management, the National Environment Policy enumerates several principles which should be kept in mind to ensure the protection and sustainable management of the environmental resources. Among those principles, the four listed below should be strongly kept in mind for a general sustainable management of Lake Cyohoha Sub-Basin's natural resources, and especially for maintenance of optimal limnological parametres susceptible to increase natural aquatic ecosystem productivity.

- economic growth in Rwanda should be based on a more rational utilisation of natural resources and take into account the environmental dimension;

- to conserve and restore ecosystems and maintain ecological and systems functioning, which are life supports, particularly the conservation of national biological diversity;
- establishment of a favourable social and economic environment for the utilisation and protection of natural resources;
- recognition of sub-regional, regional and global environmental interdependence.

Burundi and Rwanda have their national strategies and action plans as regards to biological diversity. These are documents necessary to deal with questions in connection with the conservation of aquatic ecosystems and theie biodiversity. In general, the sustainable use of the biological resources and the equitable distribution of benefit arising from the exploitation of the genetic resources is in accordance with specific policy statements elaborated as follows:

- Population and Land-use Management: balance the national policy in terms of population, land-use management and environment.
- Natural Resources: to ensure that land, which is the major resource of the country, is not degraded and used in an unplanned manner.
- Water Resources: to ensure that water quality parametres are maintained and that water is used in the various economic and social sectors without endangering environment.
- Wetlands: to improve sustainable exploitation of wetlands and conservation of their biodiversity.
- Forests and protected areas: to improve the conservation and management of forests and protected areas.
- Biodiversity: to ensure the conservation and sustainable utilisation of biodiversity of natural ecosystems and agro-ecosystems in compliance with the equitable share of benefits derived from biological resources.
- Agriculture, Livestock and Fisheries: to promote environment friendly agro-pastoral and promote appropriate fishing methods and techniques.
- Transport and Communications: to ensure compliance with environment in all transport and communications activities.
- Trade, Industry and Tourism: to integrate environmental aspects in commercial and industrial activities and promote environment friendly tourism.
- Energy and Mining: to increase energy supply while minimising the negative impact on environment and ensure compliance with the environmental dimension in mining and quarrying activities.

2.8. Legal framework governing water and wetland management

In Rwanda, the law on the environment was published in April 2005 as an organic law. This law aims to promote the natural resources management while discouraging any unforeseeable or destructive factor, to establish strategies likely to protect and reduce the harmful effects on the environment (i.e. erosion in watershed) and to rehabilitate the degraded environment (i.e. wetlands degraded). In its article 17, the law stipulates that the use and management of water resources should not use imprudent exploitation methods which can be at the origin of certain disasters, like change in water quality parametres, flooding or dryness. Any activity in connection with water resources utilisation must be beforehand subjected to an environmental impact assessment.

In September 2001, the Ministry for Lands, Environment, Forest, Water and Mines established the ministerial decree No. 2 of 24/9/01 relating to the exploitation and the management of the wetlands in Rwanda. This decree stipulates that any activity of management or exploitation of the wetland must be preceded by an environment impact assessment which must be approved by the minister responsible for environmental protection.

The organic law on land tenure, in its article 12 stipulates that the state shall decide and set aside land for envrionemental protection. This may include sections of lakes, shores of lakes and banks of rivers up to a length determined by the minister responsible for the environment.

In Burundi, the lakes, rivers and other navigable watercourses in the public domain of the State are governed by the decree of August 8, 1983. It is stipulated in its article 7 that the banks and shores of the above-mentioned watercourses belonging to public domain and have a buffer starting 10m from the line formed by the highest level reached by water during its rising period.

The law No. 1/010 of June 30, 2000 related to the Environmental Code in Burundi fixes the fundamental rules intended to allow management of the environment and protection of watersheds areas against all forms of degradation, in order to safeguard natural ecosystems and develop the rational exploitation of their resources, to prevent pollution and harmful effects, and to improve the living conditions of the population in the respective ecosystems.

The existing laws give Rwanda and Burundi the right to cooperate in the management of Lake Cyohoha Sub-Basin and above all specifically for wetlands, the two countries ratified the Ramsar Convention on Wetlands of International Importance, which emphasises government commitment to management of wetlands.

2.9 Institutional framework and actions

In the past, the institutional structures for management of environment appeared to be centralised at ministry level, but under the decentralisation system adopted in Rwanda, several activities are undertaken within the framework of the environmental projects registered in the action plan at district level.

In Lake Cyohoha Sub-Basin (Rwanda), the significant action of aforestation is the zone of plantation around the whole Lake Cyohoha up to 50m from the shore. This band also girdled by *Caesalpinia decapetala,* consists of species like *Markhamia lutea, Cassia spectabilis, Calliandra, Leucena, Grevillea robusta,* etc. Several partners are part of this action, especially NGOs and projects like RDO/HIMO under the financing of the Rwandan government. BAMPOREZE Association too has started planting bamboos around Lake Cyohoha under the financing of UNDP. This plantation of bamboos aims to protect the lake but also to provide the riparian population with a biological resource *(Bambusa vulgaris)* that is used in several handcrafts.

The Ministry for Land Use, Environment and Public Works, through the Forestry Department, is responsible for supervising all the aforestation activities. The production of seeds is made through several projects supported by several financial donors, including UNDP, FAO and the NBI (micro-grants) in favour of the populations.

With regard to soil erosion, MINAGRI is the agency responsible for the interventions. The method of digging ditches and earthwork is used in the all Bugesera region.

In Lake Cyohoha Sub-Basin, PAPSTA carries out a project for protection of the basins' slopes on pilot sites and the planting of shrubs.

Under the supervision of MINAGRI, PAPSTA carries out activities of infrastructures installation in wetlandland areas for agriculture use. It is within this framework that the wetlandlands of Akanyaru River were drained for agriculture use.

In Lake Cyohoha Sub-Basin (Burundi), the actions of aforestation are very limited. Unlike in Rwanda, there is limited form of protection by way of trees planted around the lake except observed financing of NBI (micro-grants). Other NGOs like Africa 2000 Network have shown interest in plantating bamboo on 2km stretch around the lake to protect it against siltation. This is a trans-boundary project common to both Rwanda and Burundi. There have also been isolated actions done by Catholic Relief Service (CRS) of creating contour lines along farmed slopes for the population of Marembo, in the south-east of Lake Cyohoha.

From the Burundi side, the interventions for management and development of the natural resources are carried out through several programmes set up in various official and private sectors. The actions against soil erosion are done within the framework of the Anti-erosive Campaign of the Ministry for Public Works, Environment and Land-Use through the Department of the Agricultural Engineering and Protection of the Real Estate.

In Burundi, pastoralists still exist and cattle are still led into wetland vegetation as noted in Murehe. The effects are manifested on the aquatic ecosystems and could be the contribute to changes in water characteristics.

In the area of wetland infrastructures installation, the Department of Agricultural Engineering and Protection of the Real Estate undertook activities to drain the wetland areas around Akanyaru River. In order to avoid completely drying up the wetland, appropriate measures which include making guidelines for wise use of wetlands including their buffer zones which are currently used for agricultural purposes.

In the field of nature conservation, the National Institute for Environment and Conservation of Nature (INECN) has recently undertaken an identification study for the creation of the "Protected Aquatic Landscape of Bugesera". This landscape includes all the wetlandy complex of the north of Burundi and the associated natural hills. With this action, INECN aims at "maintaining natural characteristic landscapes of national importance, harmonise interaction between man and land, while giving the public the possibility of enjoying, through activities of leisure and tourism, better living and development of economic activities in these areas." (Nzigidahera *et al*, 2005).

2.10. Recommendations in relation to Limnology

In view of the observations made during this study, the following are the recommendations:

- Stop sedimentation into aquatic ecosystems in order to prevent adverse changes in water quality and natural biotic productivity.
- Enhance best practices for wetlands exploitation and conservation to avoid accumulation of organic matter and their decomposition in bottom layers of water bodies which induce anoxic zones and inhibit development of secondary productivity (i.e Cladocera species, Cyclopoïdes nauplii, etc.).

- Restocking of micro-phytoplanktivorous fish species for a better exploitation of primary production biomass and to avoid effects of biological pollution.
- Balance inputs of mineral salts and dissolved or particulate organic matter in water body to prevent eutrophication.
- Provide water supply to communities or construct community water collection centres.
- Prepare guidelines for grazing in wetlands, shorelines and river banks.
- Promote sanitation facilities, especially at the fish-landing sites/crossing points especially to address the human faecal problems on the lake.
- Regular monitoring of limnological parametres in all aquatic ecosystems located in Lake Cyohoha Sub-Basin.
- Developing awareness on water quality maintenance and strengthening knowledge on appropriate water resources management.

2.11. Other recommendations

2.11.1. Policy, legal and institutional framework

- A harmonised management should be established for both countries to enhance conservation of the shared resources.
- Support sectoral institutionalisation for wetlands management, biodiversity, reforestation, and fisheries with emphasis on conservation.
- Develop master-plan for wetland and soil conservation management in both countries.

Managerial issues

- Develop a compressive aquatic ecosystem management plan for Lake Cyohoha Sub-Basin
- Management issues of Lake Cyohoha Sub-Basin should be integrally included in national development plans for both countries
- A comprehensive study for the evaluation of Lake Cyohoha Sub-Basin wetlands and their contribution to national economies should be conducted.
- Development of eco-tourism based on the need to conserve the Murehe and Gako woodlands, lacustrine and riverine wetlands of Lake Cyohoha and River Akanyaru which are spawning habitats and migratory points for a richer biodiversity.
- Development of ecological agriculture in hillsides and appropriated irrigation programmes in valleys, where recommended, which will increase the employment opportunities and promote modernised agriculture.
- Setting up of Lake Cyohoha South wetlands and watersheds management committees.

Conservation issues

- Lake Cyohoha Sub-Basin is proposed here for designation as a Ramsar Site. This will make it possible to preserve such a trans-boundary site of ecological, hydrological, socio-economic and climatic importance.
- Protection of wetlands ecosystems for their hydrological, ecological and socio-economic roles.
- Protection of Lake Cyohoha South and its tributaries against any kind of pollutants.
- Protection of watershed areas by development of ecological agriculture.
- Avoiding transfer of exotic species in all aquatic ecosystems located in Lake Cyohoha Sub-Basin.
- Restoration of biological community equilibrium, through maintenance of intra and inter-specific relationships among species.
- Recovering of all degraded habitats harboring richer biodiversity

Principal proposed actions

- Looking at ensuring the wise-use of the Lake Cyohoha Sub-Basin services and improved livelihood, both governments should come up with and implement the proposed following activities:
- Restoration of agro-forestry practices that ensure good watershed management, firewood for population and fodder for livestock.
- Applying soil and water conservation techniques which involve terracing, water harvesting and reforestation along aquatic ecosystems.
- Creation of the "Aquatic Protected Landscape" in both countries and reinforce it.
- Providing water supply to communities or construction of community-managed boreholes to overcome collecting water from shorelines of lakes and river banks.
- Starting rain-water harvesting from structures like houses in homesteads, schools, places of worship, commercial buildings, etc;
- Starting community-based restoration of the riparian vegetation (forests and wetlands) all around the lake and bringing both Rwanda and Burundi to common approach for this conservation issues.
- Promoting sanitation facilities, especially at the fish-landing sites/crossing points by building Ecosan toilet systems to reduce the faecal problems of the lake.
- Stopping rice growing along the streams and bays which drains sediments and other pollutants into the lake.
- Intensification of ecological agriculture production focusing on use of improved seeds, fertilisers, livestock management and rural income diversification.
- Development of non-agricultural employment innovations.
- Government to take pragmatic measures to control increasing rate of population.

Principal areas of investments

- Re-stocking the lake with selected fingerlings of commercial fishes and management of Integrated Aquaculture in closed bays for fishery industry development.
- Development of specialised ranch/park for crocodiles and turtles within closed bays in order to sell their meat and skins.
- Development of natural museums near the lake in both countries.
- Development of ski-nautical sport on the lake for tourism improvement.
- Appropriated transport facilities on the lake with severe control on releasing gas and fuel into water.
- Promotion of apiary, sericulture and papyrus exploitation (briquettes and paper-making).

There is need for capacity building in the following areas (see Table 2.13)

TABLE 2.13: Capacity building in limnological study

Themes	Sub-themes	Actors
Water Physic, chemical and microbiological study	- Water hydrodynamic survey	HLIS, CFM, MAO, TSD
	- Physic and chemical parametres measurements	HLIS, CFM, MAO, TSD
	- Water microbiological study	HLIS, CFM, MAO, TSD
	- Meteorological data collection and analysis	HLIS, CFM, MAO, TSD
Primary and secondary production evaluation	-Qualitative and quantitative phytoplankton evaluation	HLIS, CFM, MAO, TSD
	-Qualitative and quantitative zooplankton evaluation	HLIS, CFM, MAO, TSD
	- Primary and secondary production measurements	HLIS, CFM, MAO, TSD
Benthic fauna study	-Macro and micro invertebrates qualitative assessment	HLIS, CFM, MAO, TSD
	- Macro and micro invertebrates quantitative evaluation	HLIS, CFM, MAO, TSD
	-Energy transfer in trophic chains.	HLIS, CFM, MAO, TSD

2.12 Public participation and consultation issues

2.12.1. Participation of local decentralised services

For the elaboration of Master Plan of Lake Cyohoha Sub-Basin management, ministries, research institutions and high learning institutions of both countries involved in land and aquatic resources management should be consulted for complementing local expertise at sector and district levels. The aim of such consultation teams should be to evaluate and validate technically the selected projects or activities which will be implemented in the sub-basin. Decentralised administrative services should play an important role in the implementation of projects or activities programmed within the basin taking into account national and international policies, laws and institutional framework that are in line with land and aquatic resources management.

2.12.2. Participation of Beneficiaries

The people at the district and sector levels should be the promoters and beneficiaries of projects or activities initiated in the Master Plan of Lake Cyohoha Sub-Basin Management. They should be key stones in formulation of projects or activities and their implementation with the help of technical services in districts and non-governmental organisations.

For that reason, the population should be informed, aware and sensitive to all processes from conception and implementation of projects/activities related to aquatic ecosystems management. They should also be able to influence the process.

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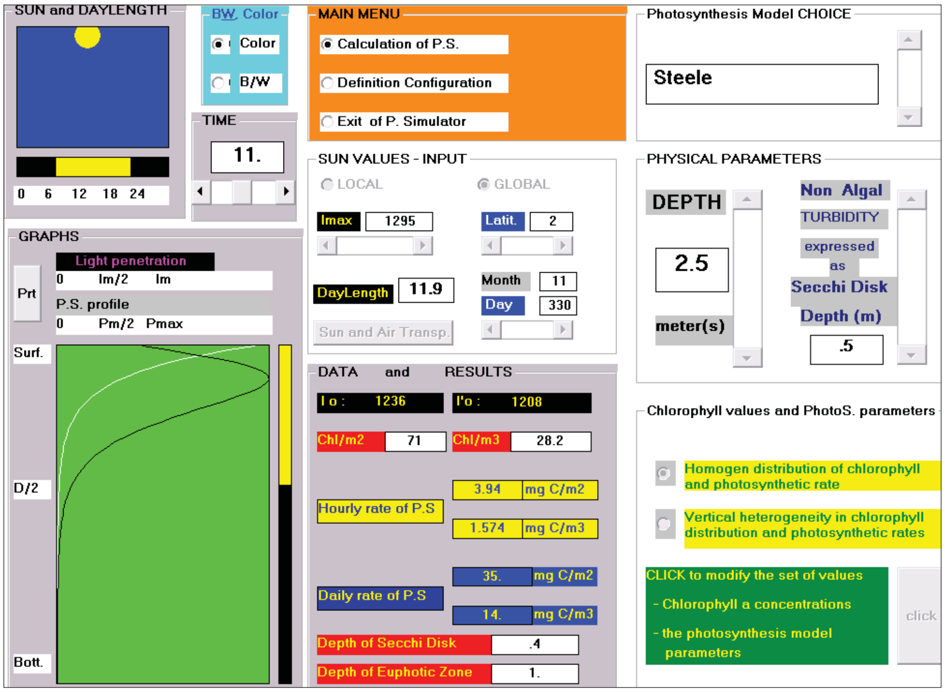
Appendices



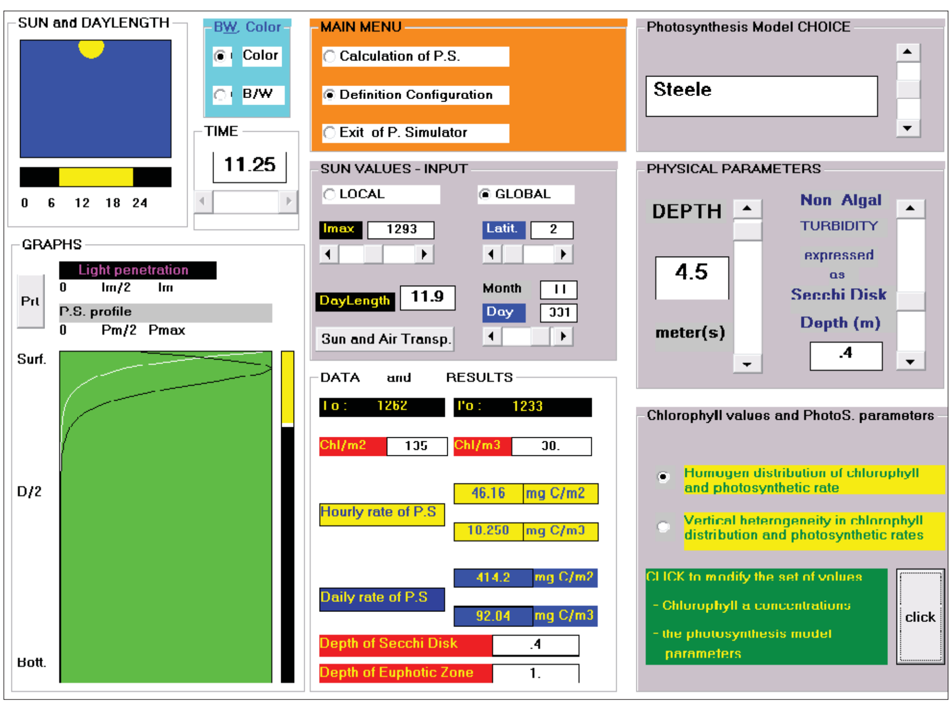


FIGURE 2.5: **Lake Cyohoha South primary productions (hour and daily) at Murambi Site calculated by utilizing Photosynthesis simulator program (A.Dauta & Capblancq, 1999).**

TABLE 2.14: Utilised parametres to estimate primary production L. Cyohoha South (Murambi site)

Secchi disk	0.52		0_2 beginning	8.5	
Io	795		**0_2 end** (mgO_2/l)	7.12	
Iopt	266		**Time length** (h)	2	11.00 – 13.00
Pmax	0.18		**Resp** (mg/L/H)	0.69	
Ke	3.653846				
Zeu (metre)	1.248				
Depth (m)	**Irradiance**	meas D.O	Net. Prod	Gross Prod	P; Model
0	795	8.50	0.00	0.69	0.07
0.1	552	8.55	0.03	0.72	0.13
0.3	266	8.85	0.18	0.87	0.18
0.5	128	8.76	0.13	0.82	0.15
0.7	62	8.66	0.08	0.77	0.09
0.9	30	8.6	0.05	0.74	0.05
Dark b. 1.1	14	8.56	0.03	0.72	0.02
1.3	7	8.56	0.03	0.72	0.01

TABLE 2.15: Utilised parametres to estimate primary production L. Cyohoha South (Bihari site)

Secchi disk	0.42	0_2 beginning	8.67	
Io	774	0_2 end	7.9	
Iopt	199	**Time length** (h)	3.10	(11.20 – 14.30)
Pmax	0.59	**Resp** (mg/L/H)	0.25	
Ke	4.52381			
Zeu (metre)	1.008			

Depth (m)	**Irradiance**	meas D.O	Net. Prod	Gross Prod	P; Model
0	774	8.65	0.05	0.30	0.13
0.1	492	8.69	0.06	0.31	0.33
0.3	199	10.32	0.59	0.84	0.59
0.5	81	9.14	0.21	0.45	0.43
0.7	33	8.95	0.15	0.39	0.22
0.9	13	8.74	0.08	0.33	0.10
Dark b. 1.1	5	7.9	-0.19	0.05	0.04
1.3	2	8.1	-0.13	0.12	0.02

FIGURE 2.16: Lake Cyohoha South primary productions (hour and daily) at Bihari Site calculated by utilizing Photosynthesis simulator program (A.Dauta & Capblancq, 1999).

TABLE 2.17: Utilised parametres to estimate primary production L. Cyohoha South (Rutonde site).

Secchi disk	0.41		0_2 beginning	8.19	
Io	794		0_2 end	8.01	
Iopt	78		**time length** (h)	1.45	
Pmax	0.57		**Resp** (mg/L/H)	0.12	
Ke	4.634146341				
Zeu (metre)	0.984				
Depth (m)	Irradiance	meas D.O	Net. Prod	Gross Prod	P; Model
0	794	8.19	0.00	0.12	0.00
0.1	500	8.23	0.03	0.15	0.02
0.3	198	8.49	0.21	0.33	0.31
0.5	78	9.01	0.57	0.69	0.57
0.7	31	8.75	0.39	0.51	0.41
0.9	12	8.51	0.22	0.34	0.21
Dark b. 1.1	5	8.2	0.01	0.13	0.09
1.3	2	8.15	-0.03	0.10	0.04

FIGURE 2.7: Lake Cyohoha South primary productions (hour and daily) at Rutonde Site calculated by utilizing

Photosynthesis simulator program (A.Dauta & Capblancq, 1999).

Chapter Three

Chapter Three

Plants of Lake Cyohoha Sub-Basin

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3.0: Introduction

The flora of Bugesera region has documented during the last fifty years. From the phyto-geographical point of view, Bugesera region is found in the Sudano-Zambezian region. The flora groups of Bugesera share many affinities with those of the Kagera area and the Ankole district in Uganda. Part of Bugesera's vegetation belongs to Lake Victoria regional mosaic (Liben, 1960; White, 1983; Nzigidahera, 2005).

In the 1960s, the savannahs were the most common form of vegetation. The farmlands occupied a restricted area with very limited farming on the edges of lakes. At that period, the forest of *Carissa oppositifolia* was reportedly already in danger. Now it is represented by some scattered groups of trees. The human population has drastically increased in the region, and this started with immigrants who arrived in Bugesera region since 1961 and they continued to come from the 1980s and the period covering 1990's to 2005 when many refugees came back to their homeland from exile. Anthropogenic activities leading to deforestation of xerophilous thickets and savannahs, drainage and clearance of vegetation for agriculture development and pasture in wetland areas innevitably modified the various types of vegetation in Bugesera region.

This study is a description of the flora in the Lake Cyohoha Sub-Basin and provides basic information needed for better understanding of the wetlands ecosystems and their biodiversity in order to achieve their effective management. The study shows the link between the ecology of the flora and livelihoods of the riparian communities and highlights some legal and institutional arrangements for the management of the flora. A list of the flora and their economic and scientific importance, and their management has been included in this report.

II. THE STUDY AREA

The study was carried out in the following localities as shwon in **FIGURE** 3.1;

- Western end of Lake Cyohoha South (Rwanda side)
- Western part of Lake Cyohoha at Kiri (No. 1)
- Eastern part of the lake (;
- Cyohoha tributary at Kagali-Ngenda (No. 2)
- Kagenge locality with two sites (Rwanda)
- Cyohoha tributary at Gahigiri (No. 5)
- Rusamaza locality (No. 6)
- Cyohoha tributary at Iyalanda, in Burundi (No. 9)
- Cyohoha tributary at Marembo, in Burundi (No. 8)
- Mugombwe locality, in Akanyaru valley, Burundi (No. 4)
- Gasenyi, in Burundi (No. 8)

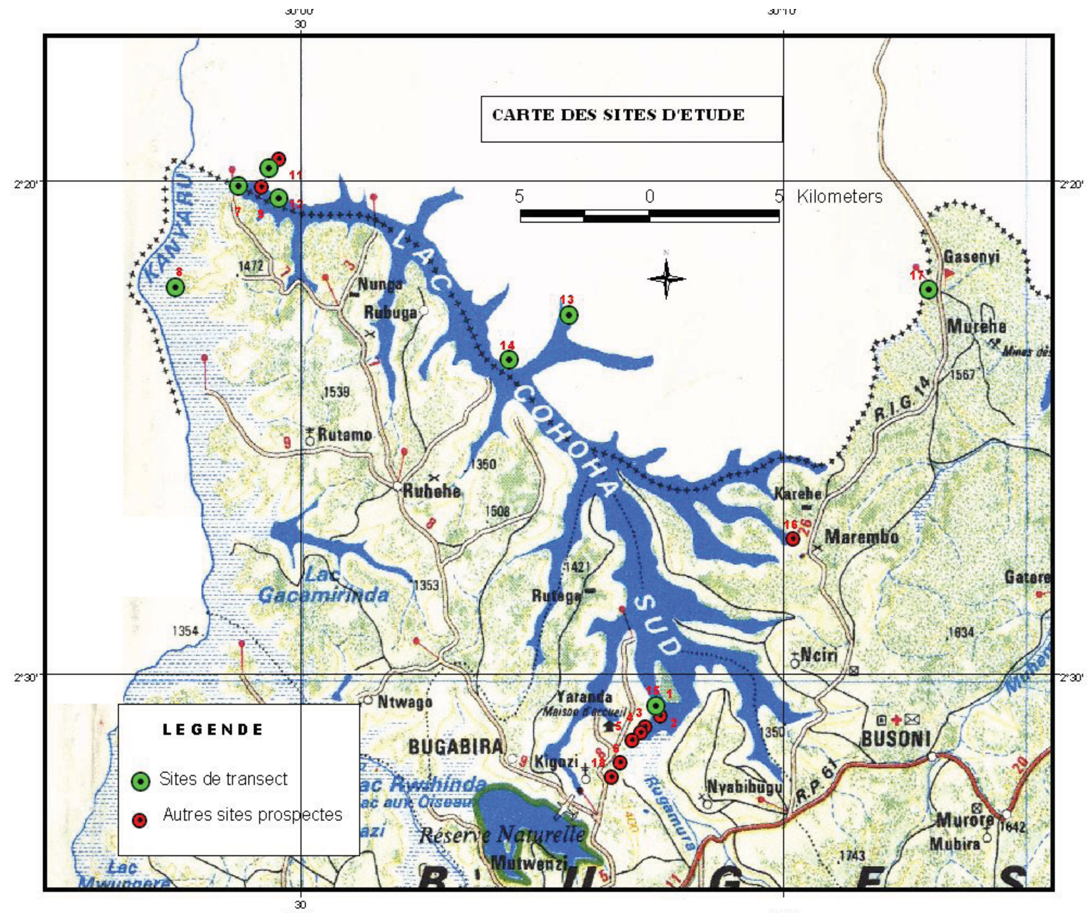


FIGURE 3.1: **Study sites**

3.1 Methods used

The methods were based on literature review and field surveys as follows:

Literature review

A literature review phase to compile accessible knowledge and information on flora assessment, socio-economic aspects of the flora utilisation as well as institutional and legal frameworks was done through visits to training and research institutions as well as public and private services in Burundi and Rwanda.

Description of the Flora in the Lake Cyohoha Sub-Basin

The analysis of the flora was done along transects at each representative site. The sites were selected according to the various floristic characteristics of the sub-basin. The observations, sampling and field photography were made throughout the transects. At each transect, species composition was established. Diagrams of the profiles that gave the image of the flora were prepared from the vegetation in wetlands, on the shores of lakes and banks of rivers and was described as one moved to the hillsides.

Link between ecology of the flora and livelihoods of the riparian communities

The analysis of the inter-relationships between the ecological system of the flora and the livelihoods of the bordering communities was approached from three levels:

a) Analysis of ecological influence of the vegetation on the socio-economic life of the population in those areas. The various ecological functions in the safeguarding of useful living resources for the population, like in pollution control and conservation for a sustainable agriculture was done.

b) Knowledge about the living things. Semi-structured interviews to know the use of plants by the local communities. The analysis also concerned the utilisation factors, the abundance of the resources and the threats. The values associated with these floristic resources were also reported.

c) Field observation to document the impact due to various activities on the conservation of plants.

Legal and institutional framework for the management of the flora

In order to document the legal and institutional framework for the management of the flora, data was collected from the following important points:

- Legal framework governing the wetlands and lakes;
- International and/or regional conventions related to aquatic ecosystems and their biodiversity, ratified by both countries;
- Current management systems applied to resources' conservation in the sub-basin;
- Scheduled wetland resources management by projects and other partners;
- Institutions and other stakeholders involved in flora management;
- Based on proposals provided by various stakeholders involved in the flora management, the legal and institutional arrangements were documented.

List of the flora species with their ecological and economic importance

Flora lists were prepared for each site surveyed highlighting the ecological and economic functions. Special attention was given to those species that are exploited for use by the local communities.

3.2 Results and discussion

3.2.1 Results from Literature review

The results of this study show flora groupings with similarities to those of the Kagera region and the Ankole district in Uganda. The Bugesera region's flora belongs to the Lake Victoria regional mosaic (White, 1983; Liben, 1960).

The vegetation of Bugesera spreads over the eastern part of Lake Rweru, in zones extending between Lakes Rweru and Cyohoha as well as wetlands bordering Akanyaru and Nyabarongo rivers. Among the described species were those of wetland areas such as *Cyperus papyrus,* a grassy savannah of *Bothriochloa insculpta* and *Themeda triandra* which colonise dry valleys, and savannah species such as *Loudetia simplex* and *Heteropogon contortus* distributed in the xeric stations composed of ochre-yellow soils.

The less xeric south-western part of the basin was colonised by a shrubby savannah of *Loudetia simplex* and *Pappea ugandensis* (= *Pappea capensis*). The shrubby savannah which was observed in the 1960s has now become localised with thickets. Due to proliferation of termites in some localities, the savannah of *Loudetia simplex* and *Heteropogon contortus* became a xeric lawn of *Brachiaria dictyoneura* and *Brachiaria eminii*. The lawn of *Ctenium concinnum* and *Elyonurus argenteus*, the most xeric of Bugesera region was localised on lateritic lithosoils and the remnant of dismantled flagstones.

The valleys, due to the colluviums sediments are colonised by a timbered savannah of *Acacia seyal (Acacia hockii)* and *Panicum maximum*. This type of vegetation also occupied important surfaces in the hilly zones bordering the eastern part of Bugesera region where the topography supported an intense deposition of colluviums sediments. Timbered savannah of *Acacia nefasia* was found on the humus-bearing alluvia in the lakes' littoral zones. From the floristic point of view, the savannah was dominated either by *Acacia sieberiana, Acacia nefasia*, or by *Acacia caffra var. campylacantha* (= *Acacia polyacantha var. campylacantha),* or by a mixture of these two species which share similar ecological requirements.

The savannah vegetation which was on the best farming soils in the 1960s has been altered by human activities for agriculture development. The herbaceous *Panicum maximun* occupies land that cleared for agriculture farming. In less exploited areas, vegetation zones of *Bridelia micrantha* and *Cordia abyssinica* predominated. The xerophilous thickets were located on the hillsides where they formed a monospecific association localised among different plant species.

There are remnants of *Carissa oppositifolia* forest and the dry forest of *Apodytes dimidiata* among the sclerophyllous forests of Bugesera region, although *Carissa oppositifolia* was already getting depopulated in the 1960s. *Apodytes dimidiata* still occupies the exposed sides of some hills.

Currently, the human activities have modified the various types of vegetation in Bugesera region. This is specifically related to the movement of immigrants which was accentuated since 1960 in Burundi as well as in Rwanda. For the case of Burundi, it was during 1961-1962 when populations come from the provinces of Kayanza and Ngozi (Nzigidahera *et al.*, 2005). Before that time, Bugesera was among the least populated areas of the country (Lebrun, 1959). But by 1972, Bugesera had already a population of 126.7 habitants/km^2 (Van der Velpen, 1973). More migrants came in 1980s, a period when Bugesera area was regarded as the granary of Burundi.

On the Rwanda side, the natural vegetation, especially that of the hillsides, was quickly cleared for agriculture and charcoal production. For example, from a 50,000 ha (according to 1983 estimates) total cover of the Bugesera wooded savannah, only less than 10,000 ha remain and constitutes pastures and nature reserve.

Most of the vegetation recorded by Liben (1960) is represented only by relics which calls for conservation measures. For example, the wooded savannah which was located on the humus-bearing alluvia in the lakes' vicinities is completely cleared, and very few rare trees of *Acacia sieberiana* and *Acacia polyacantha* have remained.

3.2.2 Vegetation distribution patterns in Lake Cyohoha South Sub-Basin

The vegetation of Lake Cyohoha South Sub-Basin is distributed in terrestrial, semi-aquatic and aquatic zones. The most important terrestrial vegetation is composed of xerophilous thickets located at Gasenyi (1,455m altitude) and covers the Rwanda nature reserve, the Murehe Natural Reserve in Burundi and the savannah of Mugomwe (1,451m). The vegetation located in wetlands includes those primarily colonised wetlands and submerged plant species in open water of Lake Cyohoha (1,345–1,350m) and Akanyaru River (1,344m).

The topographic variations in Lake Cyohoha South Sub-Basin offer various landscape aspects which harbour specific vegetation associations. These include:

Vegetation of the littoral zones of the lake

In the Lake Cyohoha shores, very little vegetation is found not exceeding a width of 10m. The vegetation is predominated by *Phragmites mauritianus,* often dispersed in the form of tuft. The transition between the aquatic environment and the terrestrial one is not clearly marked and depends on the water levels. It was observed that this area is used for cultivation, a situation found in most parts of the lake shores except at the tributaries and at some littoral zones whose bottom is sandy or stony which does not facilitate growing vegetation.

In areas beyond 10m from the lake but within less than 50m wide, *Typha domingensis* constitutes predominant vegetation. In many cases, *Typha domingensis* is bordered by a band of *Phragmites mauritianus* or, in rare cases, by *Echinochloa pyramidalis*. During the dry period, most of vegetation species disappears except some tufts of *Typha* protected by their constant position in water.

Vegetation of Akanyaru valley

The wetland of Akanyaru River extends over a length of 70km and a width of 2-4km; an area estimated to cover 200km² (Ntakimazi, 1985). C*yperus papyrus* predominates in this valley which is constantly fed by Akanyaru River and its tributaries. Several small lakes (Rwihinda, Cyohoha South, Gacamirindi, Nagitamo, Mwungere and Narungazi in Burundi and Northern Cyohoha in Rwanda) that are distributed in the region are connected to Akanyaru River by a wetland area covered by *Cyperus papyrus*. Often, the organic soils situated in the flooding zones are drained for agriculture.

Vegetation at the western end of the lake

The western end of the lake is characterised by a large wetland occupied principally by *Cyperus papyrus*. At the spot where the wetland separates Akanyaru River and Lake Cyohoha, there is a stretche of more than 2km occupied by *Typha domingensis* often cleared for agriculture development during the dry season.

The end of tha lake tributaries offer extended banks which extend over several kilometres. Thus, various types of vegetation can be found distributed from deeper water to semi-aquatic areas. The open water table is occupied by a succession of *Nymphaea lotus*, followed by large band of *Cyperus papyrus* which in turn is bordered by bands of *Typha domingensis*. In shallow areas *Cyperus papyrus* is replaced by *Typha domingensis* which predominates in those sites. Agricultural activities are developed in the less wet areas mostly occupied by *Typha domingensis.*

Hillside vegetation

Generally, there is little terrestrial natural vegetation on hillsides near Lake Cyohoha or in Akanyaru wetland because it is largely cultivated. The natural plant vegetation that exusts is represented by small herbs and shrubs.

As a consequence of continued farming, there is invasion of *Lantana camara* which is estimated to cover several square kilometres. However, certain spots of small vegetation, particularly of *Euphorbia dawei* on the hillside at Nyakarama suggested that some plant species have disappeared without being described.

It is important to note that some xerophilous vegetation on the hillsides of Rwanda-Burundi border at Gasenyi, and a degraded savannah of *Parinari curatellifolia* on the slopes bordering the Akanyaru River valley on the Burundi side still exist.

3.3 Physionomy of the vegetation of Lake Cyohoha Sub-Basin

In this sub-chapter, the physionomy of various identified plant has been done with description of the vegetation distributed in several localities. During this description, the previous work Lewalle (1972), Lebrun (1955), Habiyaremye (1994) and the wetlands classification by Montégut (1987) was followed.

3.3.1 Vegetation physionomy

From a physionomical point of view, the various types of vegetation in Lake Cyohoha Sub-Basin can be classified as follows:

- Wetlands *Cyperus papyrus*
- Xerophilous thickets
- Savannahs in degradation state
- Ruderal-nitrophilous vegetation

Wetlands

The *Cyperus papyrus* wetlands are mostly located at the western end and at certain spots of the Lake Cyohoha at altitude varying between 1,340 to 1,350m. Wetlands are also found in the Akanyaru valley at 1,400–1,420m altitude. Bikwemu (1991) classified the Akanyaru wetlands among the potential peat bogs areas and observed that the climatic conditions constitute the limiting factor of the expansion of papyrus species.

Cyperus papyrus colonises alluvial soils that are water-logged that are 4 to 5m the water edge of the lake. It can be found mixed with other species of plants which include *Ipomoea rubens* reaching 4 to 5m and a lower layer of *Thelypteris interrupta* at about 1 to 1.5m. The surface of open waters are occupied by the floating plants of *Nymphaea lotus* often covering a large area together with *Nymphaea nouchalii*. The two fixed-floating hydrophytes species were often found in channels between colonies of *Cyperus papyrus*. *Utricularia stellaris*, another free-floating hydrophyte also colonised the deep areas of water bodies, often mixed with Nymphaeaceae species.

In shallow areas, the *Cyperus papyrus* vegetation is surrounded by *Typha domingensis* reaching 3m height and covering 50m width. *Typha domingensis* is surrounded in turn by *Vossia cuspidata* or by *Echinochloa pyramidalis*. In small spaces with cool water *Enydra fluctuans* and *Hydrocotyle ranunculoides* which are also hydrophytes species predominate. Other floating hydrophytes species include *Lemna rwandensis*, *Azolla pinnatta* and *Spirodela polyrhiza*. In total, 34 aquatic and semi-aquatic species were identified. Using the classification of Montégut (1987), it was noticed that wetland area is dominated by hydrophytes and helophytes. The riparian species in the wetland areas are Riparian True Helophytes while the floating plants are True Hydrophytes. (Annex 3.1).

In summary, we can conclude that in wetland areas, the hydrophytes helophytes are obligatory colonising more wet zones, while the Riparian True helophytes grow in wetlands which are temporary and seasonally covered by water. The terrestrial helophytes are facultative wetland species usually growing in wetland but occasionally found in non-wetland areas. The list of aquatic and semi-aquatic species is presented in Annex 3.1.

Xerophilous thickets

The xerophilous thickets were found in the locality of Gasenyi belonging to the Murehe Natural Reserve at the Rwanda-Burundi border. The xerophilous thickets are distributed in degradated zones of the Kagenge in Rwanda as well as ate the end the lake tributary at Iyalanda in Burundi.

The thickets are present in form of sphere of about 10m diameter and 8m high. The thicket are generally composed of one or two shrubs of *Pappea capensis* and *Euphorbia candelabrum* which reach approximately 6 to 8m high. The thickets are mixed with species of shrubs and herbs.

It was observed that the thickets of all these localities grew on termites' mounds and were composed of almost the same plant species. Among the 100 species identified in thickets, the ligneous phanerophytes climbing groups was dominant (Annex 3.2). These are the species which form a woody cover. In the interstitial spaces with light between woody plants, you find some succulent chamaephytes. Outside the thickets, there were hemi-cryptophytes. The presence of the therophytes with small multi-seasonal ligneous herbaceous species demonstrated anthropogenic visiting to the thickets.

Savannah in degradation state

The savannahs of Lake Cyohoha Sub-Basin are being continuously degraded (i.e. Mugombwa savannah located on a rocky sloping area). From the structural point of view, savannah has lost its original physiognomy due to human activities such as cutting trees and overgrazing which completely modified the structure so that shrub of 5m high became rare.

The floristic composition of the savannah consisted of more than 23 identified species (Annex 3.3). The idebtified species are similar to those described by Liben (1960) in the south-west of Bugesera depression and which had the same flora species composition such as *Parinari mobola* (= *Parinari curatelifolia*) dominating, *Dalbergia nitidula*, and *Albizia adianthifolia*.

Ruderal-nitrophilous vegetation

The ruderal nitrophileous vegetation was well represented in Lake Cyohoha Sub-Basin with all available spaces occupied by cultivated crops from the edges of the lake and Akanyaru River to the hilltops. The intense agricultural activities constituted a principal factor in generating and maintaining ruderal and nitrophileous species. Ruderal species were found distributed under the banana plantations and in other fields.

In the vicinities of Lake Cyohoha, there is rotation between aquatic or semi-aquatic vegetation and crops. During the dry season, cultivated crops were accompanied with ruderal species such as *Galinsoga parviflora*, *Bidens pilosa*, etc. which were disappearing during flooding period.

The predominance of ruderal therophytes species such as *Ageratum conyzoides*, *Bidens pilosa*, *Galinsoga parviflora* and *Tagetes minuta* (Annex 4 and TABLE 4) was clearly found.

A grassy mass dominated by a hemi-cryptophyte *Panicum maximun*, accompanied by chamephytes in particular *Sida diversifolia*, *Triumfetta rhomboidea*, *Triumfetta tomentosa* were also identified in the study areas.

3.4: Description of Vegetation at selected observed points in the sub-basin

Western end of Lake Cyohoha

The wetland extending 2.39km between Lake Cyohoha and River Akanyaru was dominated by *Cyperus papyrus* in the past, but this has been cleared for agriculture development. Different food crops have been cultivated in this area including corn, rice, beans, groundnuts, and others. During the rainy period (March to May) water from Akanyaru River usually floods the cultivated wetland reaching Lake Cyohoha. During this period, agricultural activities are temporarily abandoned and the abandoned area is invaded by *Polygonum pulchrum* associated with *Panicum subalbidum, Heersia hexandra, Ipomoea rubens* and *Typha domingensis*. Others species found include *Ludwigia leptocarpa* with its sharp yellow flowers and *Cyperus papyrus* timidly emerging from the herbaceous group. The list of floristic species in the western end of Lake Cyohoha is presented in Annex 3.5.

Ruderal species were also found in that area such as *Ageratum conyzoides*, *Bidens pilosa*, *and Galinsoga parviflora*. In wetland areas with shallow water of approximately 10 - 50cm depth, *Hydrocotyle ranunculoides* and *Enydra fluctuans* coexisted. In channels with calm water, *Lemna rwandensis* and *Spirodela polyrhiza* were recorded. In some areas *Azolla pinnata* predominated on the former aquatic plants.

Lake Cyohoha's wetland vegetation

The vegetation in the wetland between Lake Cyohoha and Akanyaru River is predominated by *Cyperus papyrus* which occupies shallow and deep waters. *Typha domingensis* occupied more shallow areas in the vicinity of the lake. In the middle of the bay *Cyperus papyrus* continued to dominate followed by Typha *domingensis* on the contours. A fern *Thelypteris interrupta* was present in the lower part of the vegetation. Other species like *Aspilia africana, Ludwigia leptocarpa* and *Polygonum pulchrum* were also identified. *Ipomea rubens*, a voluble grass reaching 4 - 5m was found attached to *Cyperus papyrus*. In very shallow areas with a depth of water below 1m, several other species appeared particularly *Hydrocotyle ranunculoides*. In Kagali-Ngenda site, a mixture of *Cyperus papyrus* tufts and those of *Typha domingensis* was found. The limit of *Typha domingensis* bands was marked by rice growing which extended over 60m before reaching a belt of *Grevillea robusta, Cassia spectabilis*, *Leuacena* and *Cedrela* as a soil protecting plantation, those species girdled by *Caesalpinia decapetala*. The list of floristic species in wetland areas are represented in Annex 3.6.

Photo 3.1: **The species *Ipomoea rubens, Ludwigia leptocarpa* and *Aspilia africana* associated to the dominant *Cyperus papyrus*.**

Vegetation at Kagali-Ngenda

At Kagali-Ngenda (1,342m altitude), *Typha domingensis* formed a band of vegetation covering a width of 20m. Several other species, particularly *Thelypteris interrupta (=Dryopteris gongylodes)*, *Ludwigia leptocarpa* and some tufts of *Cyperus papyrus* were also recorded. Post-farming vegetation sprouted on a recently cultivated ground, dominated by *Cyperus dives* associated and species like *Polygonum pulchrum*. *Enydra fluctuans* and *Hydrocotyle ranunculoides* colonised open drainage channels dug out during rice farming period. In shallow and calm waters, *Azolla pinnatta*, *Lemna rwandensis* and *Spirodela polyrhiza* colonised the area. The transitional zone between aquatic and terrestrial areas was marked by ruderal species like *Bidens pilosa*, *Abutilon mauritianum*, *and Ageratum conyzoides*.

At the exit of this semi-aquatic zone, a protection plantation was installed on a width of 50m. The planted trees are currently 6-10m high and composed of *Markhamia lutea* and *Cassia spectabilis.* This constituted a buffer zone set up for the safeguard of Lake Cyohoha. In spaces between trees, ruderal species particularly *Bidens pilosa* dominate, *Ageratum conyzoides*, *Tagetes minuta*, *Oxygonum sinuatum* were also present. The floristic species composition of the local vegetation is represented in Annex 3.7.

Vegetation at Kagenge locality

Two sites were covered by the floristic analysis in Kagenge locality: vegetation at Gahigiri (**FIGURE** 3.3); and vegetation at the beach of Rusamaza

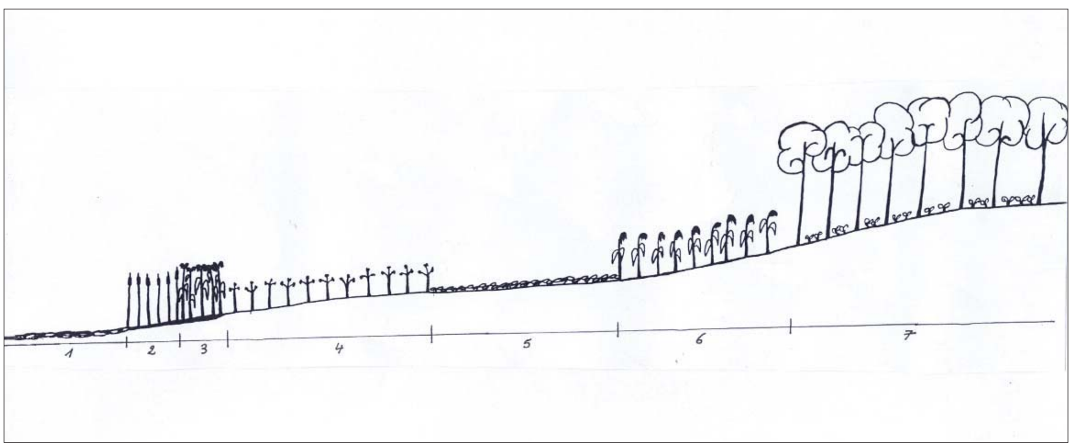
Photo 3.2: A band of *Cyperus dives* in an abandoned field at Gahigiri

Vegetation at Gahigiri

The vegetation at Gahigiri site, located in flat area at an altitude of 1,345m, is a succession of several species distributed according to water depth. In open water, two floating species are distributed: *Nymphaea lotus* distinguished by its white flowers and some *Nymphaea nouchalii* distinguished by its blue flowers. A band of *Typha domingensis* was surrounding the floating plants over a width of 40m (**Photo** 3.3). In an area with very shallow water, tufts of *Phragmites mauritianus* separated the band of *Typha domingensis* and that of *Cyperus dives*. Cyperus dives which extends over a length of 60m grows with several other species particularly *Cyperus longibracteatus* var. *longibracteatus*, *Polygonum pulchrum*, *Polygonum strigosum*, *Aspilia africana*, etc.

Within the channels used for water drainage grow a rich diversity of aquatic species like *Hydrocotyle ranunculoides*, *Enydra fluctuans* and *Azolla pinnatta*. Ruderal species were also present such as *Ageratum conyzoides*, *Commelina benghalensis*, *Bidens pilosa*, etc. *Markhamia lutea* is the predominant species in that locality. The very rich underwood herbaceous species includes particularly *Bidens pilosa* which clearly dominated others, *Tagetes minuta*, *Ageratum conyzoides*, *Galinsoga parviflora*, *Justicia* cf. *ruwenzoriensis*, *Eleusine indica*, *Conyza sumatrensis*, *Lactuca capensis*, *Hibiscus diversifolium*, *Abutilon mauritianum*, etc. This rich floristic species extended also in banana plantation dominating the sloping areas. The floristic species composition of the vegetation in Gahigiri location is represented in Annex 3.8 and Figure 3.2.

Photo 3.3: A band of *Typha domingensis* surrounding a floating carpet of Nymphaea lotus at Gahigiri



1: *Nymphaea lotus* covering water
2: *Typha domingensis* band
3: Tufts of *Phragmites mauritianus*
4: Cyperus dives band
5: *Ipomoea batatas* culture
6: *Zea mays* culture
7 : Band of protection plantation

FIGURE 3.2: Profile visualising vegetation distribution pattern at Gahigiri tributary

Vegetation of Rusamaza

Rusamaza locality of Kagenge area is found towards the centre of Lake Cyohoha. In that locality, many ruderal vegetation species were recorded in less sloping areas while in steeper areas, xerophilous thickets in degradation were found.

As a whole, the vegetation in the vicinity of Lake Cyohoha was dominated by *Phragmites mauritianus* with occurrence of rare group of *Aspilia africana* and *Achyranthes aspera*. Along the shoreline of the lake, *Cynodon nlemfuensis* follows the vegetation of *Phragmites* over a length of 50m around the lake. Several ruderal species emerged from the lawn such as *Eleusine indica*, *Oxygonum sinuatum*, *Achyranthes aspera, Commelina benghalensis, Tribulus terrestris, and Triumfetta diversifolium*. At some points, the lawn is intersected sometimes by *Caesalpinia decapetala* or *Lantana camara* which create impenetrable rustles, thus eliminating the underwood species. In the areas with unsuitable lands for agriculture, the group of thickets were particularly dominant with the following species: *Capparis fascicularis*, *Pappea capensis*, *Grewia similis*, *and Grewirea mollis*.

A protection plantation which covered almost 50m width comprised the following plant species: *Cassia spectabilis* and *Markhamia lutea*. The underwood species included several small ligneous, multi-seasonal and perennial plants such as *Senna occidentalis*, *Tephrosia nana*, *Indigofera arrecta*, *Clerodendrum rotundifolium*, *Clerodendrum myricoides, Abutilon mauritianum,* etc.

After the protection plantation, there is a farming zone where a certain number of species still exist such as *Acacia polyacantha, Kigelia africana,* and *Acacia hockii.* It is presumable that in the past, the hillsidess of Rusamaza were covered by wooded savannahs, with *Acacia* group contiguous to xerophilous thickets. The floristic species composition in Rusamaza locality is in table Annex 3.9.

Photo 3.4: **A relic xerophilous thicket of Pappea capensis in Rusamaza locality.**

Vegetation at Iyalanda

The southern part of Lake Cyohoha is very dendritic. The vegetation of the Iyalanda tributary started with a floating biocover predominated by *Nymphaea lotus* and some individuals of *Nymphaea nouchalii* at 1.5m depth. A species of Lentibulariaceae, *Utricularia stellaris*, is distributed between the large leafs of *Nympahea*. In the direction of the sloping area, Nymphaeaceae group is girdled by a band of *Typha domingensis* which covered almost 40m width (**Photo** 3.5).

Photo 3.5: *Nymphaea lotus* girdled by a band of *Typha domingensis*

After this band of *Typha domingensis*, *Vossia cuspidata* forms a small band over a width not exceeding 5m. More species such as *Enydra fluctuans*, *Spilanthes mauritiana*, *Sphaeranthus suaveolens*, *Hydrocotyle ranunculoides* and *Ludwigia stolonifera* were also present in the site. The remarkable floristic species in this locality were old *Markhamia lutea* trees which occupied the whole catchment areas. Some large trees like *Acacia polyacantha*, *Ficus vallis-choudae*, *Ficus thonningii*, etc were also recorded in that area.

In the direction of the head of tributary, the floating cover of *Nymphaea lotus* was delimited by a homogeneous dense *Cyperus papyrus* in deeper water, which was girdled by *Typha domingensis* and the latter in turn was surrounded by *Vossia cuspidata*. Areas cleared for agricultural activities were dominated by *Panicum subalbidum* accompanied by *Aspilia africana*, *Polygonum pulchrum*, etc. covering a length of more than 180m.

Towards the head of the tributary, various crops are grown. The local population reported that before 1993, this zone was formerly covered by *Cyperus latifolius,* and its remaining tufts were still observed within the channels used for agriculture drainage.

Xerophilous thickets in the valley

The higher part of the valley was considered as poor for agricultural development due to repetitive ploughing and overgrazing which is still practiced in the area. The area is used for grazing and has a lot of termite mounds.

Different species of xerophilous thickets were recorded such as *Phoenix reclinata*, *Grewia similis*, *Grewia mollis*, *Capparis fascicularis* and several lianas like *Cissus oliveri*, and *Sarcostemma viminale*.

This illustrates the xerophilous phenomena already experienced on the hillsides and which is likely to invade all the valleys due to uncontrolled drainage and climate changes in the area.

The current spread of *Lantana camara* in the area threatens, together with the expansion of the xerophilous thickets, to occupy the drained wetland zones. The floristic species composition of the vegetation is shown in Annex 3.10.

Photo 3.6: *Typha domingensis* surrounded by *Echinochloa pyramidalis* and *Vossia cuspidata* towards the edges

Photo 3.7: *Typha* is appearing in a grassy mass dominated by *Polygonum pulchrum*

Photo 3.8: Iyalanda tributary is marked by the appearance of thickets on termitarias

Vegetation of Marembo tributary

At Marembo, vegetation is characterised by a floating biocover composed of *Nymphaea lotus,* extending 80m and girdled by a band of *Vossia cuspidate.* The latter is in turn surrounded by *Cyperus dives* in the recently cultivated zone and extends to over a 100m width. At the edges of the tributary, typha species dominate and are limited by food crops of *Ipomoea batatas, Solanum tabacum, and Zea mays*. In the catchment areas, several trees were found dispersed such as *Markhamia lutea*, *Acacia polyacantha*, and *Ficus vallis-choudae*.

Vegetation at Mugombwe

The vegetation at Mugombwe includes both Akanyaru valley vegetation and degraded savannah on the hillside bordering the valley.

Akanyaru valley

Akanyaru wetlandland area was subjected to farming activities on Rwanda side as well as in Burundi. However, on the Burundi side, 15 buffer zones were created all along the Akanyaru River. At Mugombwe, the buffer zone covered almost 600m width with vegetation dominated by Cyperus papyrus. Gradually, farming activities were developed in Akanyaru wetland areas, decreasing by the buffer zones areas.

Ploughing and overgrazing activities were recognised in buffer zones which clearly modified the floristic species composition in those areas. Ruderal and post-farming flora species such as *Ageratum conyzoides*, *Bidens pilosa*, *Polygonum pulchrum*, *Cyperus dives*, *and Panicum maximum* were recorded.

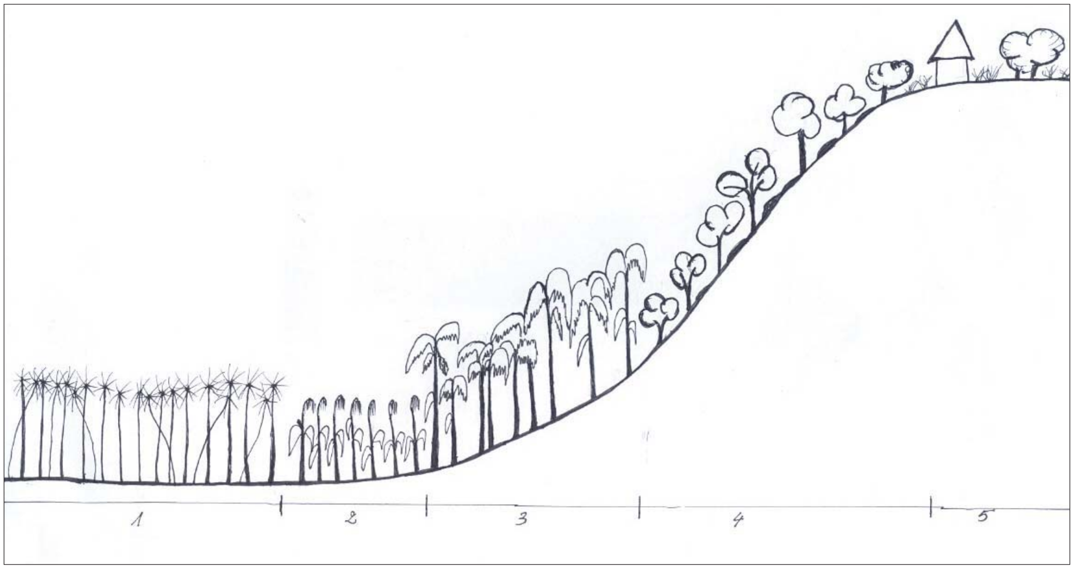
Towards the valley, banana plantations were found (FIGURE 3.3). Ruderal species were also present there. *Bidens pilosa* predominated followed by *Oxygonum sinuatum*, *Tribulus terrestris*, *Ageratum conyzoides*, etc.

Degradated Savannah

Floristic species composition in savannah was mostly composed of *Parinari curatellifolia*, *Lannea schimperi*, *Ozoroa reticulata*, *Albizia adianthifolia* and *Combretum molle*. The vegetation distribution is shown in **Photo** 3.9 and the floristic species composition listed in Annex 3.11.

Photo 3.9*:* *Cyperus papyrus* degradated in a buffer zone of Akanyaru valley

Photo 3.10: Development of Agriculture by clearing *Cyperus papyrus* of Akanyaru valley



1 : *Cyperus papyrus* wetland
2 : *Zea mays* culture
3 : Banana plantation band
4 : Wooded savannah on roch ground
5: Crops and houses

FIGURE 3.3: Vegetation Distribution profile at Mugombwe

Xerophilous thickets at Gasenyi site

The xerophilous thickets at Gasenyi site constitute continuous vegetation of the nature reserve on the Rwanda side and the vegetation of Murehe Natural Reserve in Burundi.

The principal trees of the thickets are *Euphorbia candelabrum*, *Pappea capensis* and *Lannea schimperi*, reaching 6 to 10m height. The tangle appears at the lower layer with shrubby species such as *Canthium lactescens, Teclea nobilis, Gardenia ternifolia* subsp. *jovis-tonantis,* enriched with climbing species and rustles like *Grewia mollis*, *Grewia similis*, *Flueggea virosa*, *Capparis fascicularis*, *Ziziphus mucronata* and *Scutia myrtina.* At the top of thicket, a group of lianas including *Cissus oliveri* cover the upper part (**FIGURE** 3.11). Species like *Sansevieria dawei*, *Sansevieria cylindrica*, *and Aloe macrosiphon* were growing under the thickets. Between thickets, species like *Brachiaria eminii* form a very poor plant cover. Usually, the thickets are separated by small shrubs of *Acacia hockii* and *Dicrostachys cinerea* with some graminaceous species like *Panicum maximum, Themeda triandra* and *Hyparrhenia filipendula*

The floristic species composition of *Xerophilous thickets* is listed in Annex 3.12.

Photo 3.11: The xerophilous thickets of Gasenyi

Annex 3.1: List of aquatic and semi-aquatic species and their typology.

Aquatic and semi-aquatic plants	***Scientific Name***	***Typology (Montégut, 1987)***
No floating plants		
Dominant	*Cyperus papyrus*	Helophyte Hydrophyte
	Typha domingensis	Helophyte Hydrophyte
Abundant	*Aspilia africana*	Terrestrial Helophyte
	Cyperus dives	Helophyte Hydrophyte
	Cyperus laevigatus	Helophyte hydrophyte
	Enydra fluctuans	Riparian True Helophyte
	Heersia hexandra	Riparian True Helophyte
	Hydrocotyle ranunculoides	Riparian True Helophyte
	Ipomoea rubens	Riparian True Helophyte
	Ludwigia leptocarpa	Riparian True Helophyte
	Panicum subalbidum	Riparian True Helophyte
	Phragmites mauritianus	Riparian True Helophyte
	Thelypteris interrupta	Riparian True Helophyte
	Vossia cuspidata	Helophyte Hydrophyte
Scattered species	*Commelina diffusa*	Riparian True Helophyte
	Crassocephalum montuosum	Terrestrial Helophyte
	Cyperus longibracteatus var. *longibracteatus*	Riparian True Helophyte
	Cyperus latifolius	Helophyte hydrophyte
	Echinochloa pyramidalis	Riparian True Helophyte

	Hemarthria natans	Riparian True Helophyte
	Ludwigia abyssinica	Riparian True Helophyte
	Polygonum pulchrum	Riparian True Helophyte
	Polygonum strigosum	Riparian True Helophyte
	Pycreus capillifolius	Riparian True Helophyte
	Sesbania sesban var. *nubica*	Terrestrial Helophyte
	Sphaeranthus suaveolens	Terrestrial Helophyte
	Spilanthes mauritiana	Terrestrial Helophyte
Floating plants		
	Azolla pinnatta	Free-Floating Hydrophyte
	Lemna rwandensis	Free-Floating Hydrophyte
	Nymphaea lotus	Fixed-Floating Hydrophyte
	Nymphaea nouchalii	Fixed-Floating Hydrophyte
	Pistia stratiotes	Free-Floating Hydrophyte
	Utricularia stellaris	Free-Floating Hydrophyte
	Spirodela polyrhiza	Free-Floating Hydrophyte

Annex 3.2 : List of xerophillous thickets species in Lake Cyohoha Sub-Basin.

Xerophillous thickets plants	**Scientific Name**	**Biological Forms**
Large trees dominating the Thickets		
	Pappea capensis	Erect Ligneous Phanerophyte
	Euphorbia candelabrum	Succulent Phanerophyte
Shrubby species or climbing lianas		
Dominant	*Acokanthera schimperi*	Erect Ligneous Phanerophyte
	Lannea schimperi	Erect Ligneous Phanerophyte
	Capparis erythrocarpus	Erect Ligneous Phanerophyte
	Capparis fascicularis	Climbing Phanerophyte
	Carissa spinarum	Climbing Phanerophyte
	Euclea racemosa subsp. *schimperi*	Erect Ligneous Phanerophyte
	Maytenus heterophylla	Erect Ligneous Phanerophyte
	Teclea nobilis	Erect Ligneous Phanerophyte
	Ziziphus mucronata	Erect Ligneous Phanerophyte
Abundant species	*Allophylus africana*	Erect Ligneous Phanerophyte
	Asparagus falcatus	Climbing Phanerophyte
	Canthium schimperanum	Erect Ligneous Phanerophyte
	Canthium latescens	Erect Ligneous Phanerophyte
	Cissampelos mucronata	Climbing Chamaephyte
	Cissus oliveri	Climbing Phanerophyte
	Clausena anisata	Erect Ligneous Phanerophyte
	Cyphostemma adenocaule	Rhizomateous Geophyte
	Dichrostachys cinerea	Erect Ligneous Phanerophyte
	Grewia mollis	Erect Ligneous Phanerophyte
	Grewia similis	Erect Ligneous Phanerophyte
	Jasminum fluminense	Climbing Phanerophyte
	Jasminum dichotomum	Climbing Phanerophyte
	Olea europea subsp. *Cuspidata*	Erect Ligneous Phanerophyte
	Strychnos lucens	Erect Ligneous Phanerophyte

	Commiphora africana	Erect Ligneous Phanerophyte
Scattered species	*Acacia hockii*	Erect Ligneous Phanerophyte
	Acalypha cf. *bipartita*	Phanerophyte (Chamaephyte)
	Albizia adianthifolia	Erect Ligneous Phanerophyte
	Albizia versicolour	Erect Ligneous Phanerophyte
	Apodytes dimitiata	Erect Ligneous Phanerophyte
	Bambekea racemosa	Climbing Chamaephyte
	Caesalpinia decapetala	Climbing Phanerophyte
	Combretum molle	Erect Ligneous Phanerophyte
	Clerodendrum myricoïdes	Sub-ligneous Chamaephyte
	Combretum collinum	Erect Ligneous Phanerophyte
	Canthium sp.	
	Crabbea velutina	Hemicryptophyte
	Cynanchum schistoglossum	Climbing Chamaephyte
	Cynanchum validum	Climbing Chamaephyte
	Dalbergia nitidula	Erect Ligneous Phanerophyte
	Dodonea angustifolia	Erect Ligneous Phanerophyte
	Entada abyssinica	Erect Ligneous Phanerophyte
	Erythroccoca bongensis	Erect Ligneous Phanerophyte
	Flueggea virosa	Erect Ligneous Phanerophyte
	Gardenia ternifolia subsp. *Jovis-tonantis*	Erect Ligneous Phanerophyte
	Gardenia imperialis	Erect Ligneous Phanerophyte
	Gongonema angolense	Climbing Phanerophyte
	Haplocoelum gallaense	Erect Ligneous Phanerophyte
	Hippocratea africana	Phanerophyte
	Ipomoea cairica	Climbing Chamaephyte
	Landolphia kirkii	Climbing Phanérophyte
	Maerua angolense	Erect Ligneous Phanerophyte
	Maerua triphylla ssp. *Jahannis*	Erect Ligneous Phanerophyte
	Maytenus arbutifolia	Erect Ligneous Phanerophyte
	Maytenus senegalensis	Erect Ligneous Phanerophyte
	Osyris quadripartita	Erect Ligneous Phanerophyte
	Ozoroa reticulata	Erect Ligneous Phanerophyte
	Pavetta assimilis	Erect Ligneous Phanerophyte
	Pavetta oliverana	Erect Ligneous Phanerophyte
	Phoenix reclinata	Erect Ligneous Phanerophyte
	Pittosporum spathicalyx	Erect Ligneous Phanerophyte
	Rhoicissus tridentata	Phanerophyte grimpant
	Rhus longipes	Erect Ligneous Phanerophyte
	Rhynchosia resinosa	Chamaephyte
	Rytigynia monanta	Erect Ligneous Phanerophyte
	Sarcostemma viminale	Climbing Succulent Phanerophyte
	Schrebera alata	*Phanerophyte*
	Scutia myrtina	Erect Ligneous Phanerophyte
	Senecio hadiensis	Climbing phanerophyte
	Strychnos innocua	*Erect Ligneous Phanerophyte*
	Strychnos spinosa	Erect Ligneous Phanerophyte
	Teclea trichocarpa	Erect Ligneous Phanerophyte

	Ximenia caffra	Erect Ligneous Phanerophyte
	Zanthoxyllum chalybeum	Erect Ligneous Phanerophyte
Underwood species in thickets		
	Achyranthes aspera	Climbing Chamaephyte
	Aerva lanata	Therophyte
	Aloe bukobana	Succulent Chamaephyte
	Aloe macrosiphon	Succulent Chamaephyte
	Asparagus flagellaris	Climbing Phanerophyte
	Caraluma schweinfurthii	Decumbent Succulent Chamaephyte
	Chlorophytum sparsiflorum	Geophyte
	Commelina elgonensis	Decumbent Chamaephyte
	Orchidaceae (indet.)	Geophyte
	Pupalia lappacea	
	Sansevieria cylindrica	Succulent Chamaephyte
	Sansevieria dawei	Succulent Chamaephyte
	Solanum nigrum	Therophyte (Chamaephyte)
Herbaceous species between the thickets		
	Desmodium salicifolium var. densiflorum	Chamaephyte (Phanerophyte)
	Hibiscus diversifolius	Phanerophyte (Chamaephyte)
	Hyparrhenia filipendula	Cespitose Hemicryptophyte
	Indigofera arrecta	Phanerophye
	Indigofera sp.	
	Indigofera zenkeri	Sub-ligneous Chamaephyte
	Oxygonum sinuatum	Therophyte
	Panicum maximum	*Cespitose Hemicryptophyte*
	Phyllantus odontadenius	Phanerophyte
	Senna occidentalis	Therophyte (Hemicryptophye)
	Sida alba	Therophyte (Chamaephyte)
	Themeda triandra	Cespitose Hemicryptophyte

Annex 3.3: List of savannah species in Cyohoha South Sub-Basin.

Savannah plants	Scientific Name	Biological forms
Dominant	*Parinari curatellifolia*	Erect Ligneous Phanerophyte
	Albizia adianthifolia	Erect Ligneous Phanerophyte
	Acokanthera schimperi	Erect Ligneous Phanerophyte
	Lannea schimperi	Erect Ligneous Phanerophyte
	Combretum collinum	Erect Ligneous Phanerophyte

Abundant	*Albizia versicolour*	Erect Ligneous Phanerophyte
	Canthium lactescens	Erect Ligneous Phanerophyte
	Canthium schimperanum	Erect Ligneous Phanerophyte
	Combretum molle	Erect Ligneous Phanerophyte
	Dalbergia nitidula	Erect Ligneous Phanerophyte
	Strychnos lucens	Erect Ligneous Phanerophyte
Scattered	*Haplocoelum gallaense*	Erect Ligneous Phanerophyte
	Dovyalis macrocalyx	Erect Ligneous Phanerophyte
	Landolphia kirkii	Erect Ligneous Phanerophyte
	Maytenus heterophylla	Erect Ligneous Phanerophyte
	Ochna schweinfurthii	Erect Ligneous Phanerophyte
	Ozoroa reticulata	Erect Ligneous Phanerophyte
	Pittosporum spathicalyx	Erect Ligneous Phanerophyte
	Securidaca longededunculata	Erect Ligneous Phanerophyte
	Uvaria angolensis	Erect Ligneous Phanerophyte
	Vernonia perrottetii	Therophyte

Annex 3.4: List of ruderal-nitrophilous species in Lake Cyohoha Sub-Basin.

Ruderal-nitrophilous vegetation	**Scientific Name**	**Biological forms**
Dominant	*Ageratum conyzoides*	Therophyte
	Bidens pilosa	Therophyte
	Conyza sumatrensis	Therophyte
	Cynodon nlemfuensis	Procument Chamaephyte
	Galinsoga parviflora	Therophyte
	Panicum maximum	Hemicryptophyte
	Tagetes minuta	Therophyte
	Eleusine indica	Therophyte
Abundant	*Achyranthes aspera*	Procument Chamaephyte
	Asystasia gangetica	Procument Chamaephyte
	Commelina benghalensis	Procument Chamaephyte
	Tribulus terrestris	Therophyte
	Trichodesma zeylanicum	Hemicryptophyte
	Cenchrus ciliaris	Therophyte
	Digitaria abyssinica	Geophyte
	Euphorbia heterophylla	Therophyte
	Oldenlandia herbacea	Therophyte

Scattered plants	*Abutilon mauritianum*	Therophyte
	Aerva lanata	Sub-ligneous Chamaephyte (Therophyte)
	Agrocharis incognita	Hemicrytophyte
	Amaranthus viridis	Therophyte
	Cardiospermum halicacabum	Therophyte
	Centella asiatica	Chamaephyte
	Crassocephalum montuosum	Erect Chamaephyte
	Cyperus longibracteatus	Geophyte
	Cyperus sp.	
	Cyperus sumatrensis	Geophyte
	Dactyloctenium aegyptium	Therophyte
	Desmodium salicifolium var. salicifolium	Chamaephyte (Phanerophyte*)*
	Hibiscus diversifolius	Phanerophyte (Chamaephyte)
	Ipomoea cairica	Climbing Chamaephyte
	Ipomoea sp.	
	Justicia cf.. *ruwenzoriensis*	
	Justicia uncinulata	Chamaephyte
	Kyllinga sp.	
	Lagenaria abyssinica	ClimbingChamaephyte
	Mariscus sumatrensis	Rhizomateous Geophyte
	Ocimum cf. *basilicum*	Therophyte
	Oldenlandia goreensis	Therophyte (Chamaephyte)
	Oxalis corniculata	Hemicryptophyte
	Oxygonum sinuatum	Therophyte
	Panicum heterostachyum	Hemicryptophyte
	Phyllantus odontadenius	Phanerophyte
	Polygonum salicifolium	Therophyte (Geophyte)
	Rhynchelytrum repens	Therophyte
	Ricinus communis	Phanerophyte
	Senna occidentalis	Therophyte (Hemicryptophye)
	Sida diversifolia	Phanerophyte (Chamaephyte)
	Sorghum arundinaceum	Therophyte
	Spermacoce princecae	Procument Chamaephyte
	Thunbergia alata	Chamaephyte grimpant
	Triumfetta rhomboidea	Procument Chamaephyte
	Triumfetta tomentosa	Chamaephyte
	Triumfetta diversifolium	Chamaephyte
	Vernonia sp.	

Annex 3.5: Flora species censured in the termination of Lake Cyohoha South at Kiri.

Types of vegetation	**Scientific Name**	**Local Name (Kirundi or Kinyarwanda)**
Aquatic or semi-aquatic vegetation	*Typha domingensis*	Umuberanya
	Cyperus papyrus	Urufunzo
	Spirodela polyrhiza	
	Hydrocotyle ranunculoides	
	Lemna rwandensis	

	Azolla pinnata	
	Cyperus dives	Ikigaga
	Enydra fluctuans	
	Polygonum pulchrum	Igorogonzi
	Heersia hexandra	Umudihidihi
	Panicum subalbidum	Urwiri rwomurufunzo
	Ipomoea rubens	
	Nymphaea lotus	Irebe
	Aspilia africana	Icumwa
	Ludwigia leptocarpa	
	Pycreus capillifolius	
Ruderal vegetation	*Commelina benghalensis*	Inteza
	Bidens pilosa	Irebe
	Galinsoga parviflora	Icumwa
	Crassocephalum montuosum	

Annex 3.6: List of floristic species in wetlandland areas.

Types of vegetation	Scientific name	Local Name (Kirundi or Kinyarwanda)
Vegetation of Cyperus papyrus	*Cyperus papyrus*	Urufunzo
	Typha domingensis	Umuberanya
	Thelypteris interrupta	
	Polygonum pulchrum	Igorogonzi
	Ipomoea rubens	
	Ludwigia leptocarpa	
	Panicum subalbidum	Urwiri rwo murufunzo
	Aspilia africana	Icumwa
	Cyperus laevigatus	
	Crassocephalum montuosum	
	Enydra fluctuans	
	Hemarthria natans	
Floating vegetation	*Nymphaea nouchalii*	Irebe
	Pistia stratiotes	

Annex 3.7: List of floristic species at Kagali-Ngenda

Types of vegetation	Species Name	Local name (Kirundi or Kinyarwanda)
Band of *Typha* domingensis	*Aquatic and semi-aquatic species*	
	Typha domingensis	Umuberanya
	Cyperus papyrus	Urufunzo
	Thelypteris interrupta	
	Ludwigia leptocarpa	
	Cyperus laevigatus	
	Aspilia africana	Icumwa
Post-farming vegetation	*Aquatic and semi-Aquatic species*	
	Cyperus dives	Ikigaga
	Typha domingensis	Umuberenya

	Polygonum pulchrum	Igorongonzi
	Polygonum strigosum	
	Enydra fluctuans	
	Hydrocotyle ranunculoides	
	Nymphaea nouchalii	
	Ludwigia leptocarpa	
	Ludwigia abyssinica	
	Azolla pinnatta	
	Commelina benghalensis	Inteza
	Lemna rwandensis	
	Spirodela polyrhiza	
	Crassocephalum montuosum	
	Terrestrial areas species	
	Bidens pilosa	
	Abutilon mauritianum	
	Achyranthes aspera	
	Amaranthus viridis	
	Triumfetta rhomboidea	
	Ageratum conyzoides	
Protection band	*Planted species*	
	Markhamia lutea	
	Cassia spectabilis	
	Underwood species composition	
	Bidens pilosa	
	Ageratum conyzoides	
	Tagetes minuta	
	Achyranthes aspera	
	Justicia cf. *ruwenzorensis*	
	Asystasia gangetica	
	Achyranthes aspera	
	Oxygonum sinuatum	
	Ricinus communis	
	Abutilon mauritianum	
	Cenchrus ciliaris	
	Eleusine indica	Urwanfu
	Cyperus longibracteatus var. *longebracteatus*	
	Crassocephalum montuosum	
	Cynodon nlemfuensis	Urucaca
	Digitaria abyssinica	
	Lagenaria abyssinica	
	Ipomoea cairica	
	Sida diversifolia	
	Triumfetta tomentosa	
	Galinsoga parviflora	
	Panicum heterostachyum	
	Tribulus terrestris	
	Dactyloctenium aegyptium	
	Cyperus sumatrensis	
	Cyperus sp.	
	Justicia uncinulata	

	Oxalis corniculata	
	Rhynchelytrum repens	
Species in cultivated areas	*Flueggea virosa*	
	Carissa spinarum	
	Rhus natalensis	Umusagara
	Maytenus arbutifolia	
	Vernonia amygdalina	Umubirizi

Annex 3.8: Floristic composition of the vegetation at Gahigiri/Kagenge locality.

Types of vegetation	**Scientific Name**	**Local Name (Kirundi or Kinyarwanda)**
Floating vegetation	Floating species	
	Nympahea lotus	Irebe
	Nymphaea nouchalli	Irebe
Vegetation of *Typha domingensis*	*Watery and semi-watery species*	
	Typha domingensis	Umuberanya
	Nymphaea nouchalli	Irebe
	Phragmites mauritianus	
	Hydrocotyle ranunculoides	
	Enydra fluctuans	
	Sesbania sesban var. nubica	Umunyegenyege
Vegetation of *Cyperus dives*	*Watery and semi-watery species*	
	Cyperus dives	Ikigaga
	Polygonum pulchrum	Igorogonzi
	Polygonum strigosum	Igorogonzi
	Enydra fluctuans	
	Heersia hexandra	
	Hydrocotyle ranunculoides	
	Azolla pinnatta	
	Lemna rwandensis	
	Spirodela polyrhiza	
	Ludwigia leptocarpa	
	Cyperus longibracteatus var. longibracteatus	
	Terrestrial species	
	Bidens pilosa	Icanda
	Commelina benghalensis	
	Ageratum conyzoides	Akarura
Protection band	*Planted species*	
	Markhamia lutea	
	Underwood species	
	Bidens pilosa	Icanda
	Ageratum conyzoides	
	Tagetes minuta	Umunutsi, Urumogimogi
	Achyranthes aspera	Urukaramu
	Justicia cf.. ruwenzoriensis	
	Asystasia gangetica	
	Galinsoga parviflora	Kurisuka
	Eleusine indica	Urwamfu

	Conyza sumatrensis	
	Hibiscus diversifolium	
	Abutilon mauritianum	
	Trichodesma zeylanicum	Urwiba

Annex 3.9: List of floristic species at Rusamaza site.

Types of vegetation	**Scientific name**	**Local name (Kirundi or Kinyarwanda)**
Vegetation of *Phragmites mauritianus*	*Aquatic and semi-aquatic species*	
	Phragmites mauritianus	Umuberanya
	Aspilia africana	Icumwa
	Ludwigia leptocarpa	
Lawn of *Cynodon nlemfuensis*	*Ruderal species*	
	Tribulus terrestris	
	Triumphetta diversifolium	
	Commelina benghalensis	Inteza
	Achyranthes aspera	
	Oxygonum sinuatum	
	Eleusine indica	
	Ageratum conyzoides	Akarura
	Bidens pilosa	
	Oldenlandia goreensis	
	Galinsoga parviflora	
	Polygonum salicifolium	
	Euphorbia heterophylla	
	Panicum heterostachyum	
	Panicum maximum	Igikaranka
	Asystasia gangetica	
	Senna occidentalis	
	Lagenaria abyssinica	
	Digitaria abyssinica	
	Phyllantus odontadenius	
	Agrocharis incognita	
	Triumfetta tomentosa	
	Triumfetta rhomboidea	
	Tagetes minuta	
	Amaranthus viridis	
	Cyperus longibracteatus	
	Sorghum arundinaceum	
	Vernonia sp.	
	Centella asiatica	
	Conyza sumatrensis	
	Abutilon mauritianum	
	Mariscus sumatrensis	
	Ipomoea cairica	
	Ipomoea sp.	
	Ocimum cf. *basilicum*	
	Kyllinga sp.	
	Desmodium salicifolium var. salicifolium	

	No ruderal species	
	Harrisonia abyssinica	
	Caesalpinia decapetala	Umubambangwe
	Flueggea virosa	
	Lantana camara	Umuhengerihengeri
Species in protection band	Planted species	
	Markhamia lutea	Umusave
	Cassia spectabilis	Umutarabanyi
	Underwood species	
	Senna occidentalis	
	Tephrosia nana	
	Bidens pilosa	
	Ageratum conyzoides	Akarura
	Indigofera arrecta	
	Achyranthes aspera	
	Clerodendrum myricoides	
	Clerodendrum rotundifolium	
	Galinsoga parviflora	Kurisuka
	Eleusine indica	Urwanfu
	Conyza sumatrensis	
	Hibiscus diversifolium	
	Abutilon mauritianum	
	Lantana rhodesiensis	Umuhengerihengeri
	Trichodesma zeylanicum	Urwiba
Degradated Xerophilous thickets	***Shrubby and climbing lianas***	
	Capparis fascicularis	
	Grewia similis	Umukoma
	Grewia mollis	Umukoma
	Pappea capensis	
	Cyphostemma adenocaule	
	Cissus oliveri	
	Cynanchum schistoglossum	
	Gongonema angolense	
	Jasminum fluminense	
	Olea europaea subsp. cuspidata	
	Jasminum dichotomum	
	Maytenus arbutifolia	
	Carissa spinarum	
	Ziziphus mucronata	
	Asparagus falcatus	
	Cynanchum validum	
	Bambekea racemosa	
	Teclea nobilis	
	Teclea trichocarpa	
	Maerua angolense	
	Rhus longipes	Umusagara
	Pavetta oliverana	
	Ipomoea cairica	
	Hippocratea africana	
	Cissampelos mucronata	
	Maerua triphylla ssp. *Jahannis*	
	Herbaceous in the underwood	

	Achyranthes aspera	
	Sansevieria dawei	
	Solanum nigrum	
	Pupalia lappacea	
Agriculture zone	***Relictual species***	
	Acacia polyacantha	Umugunga
	Kigelia africana	Umuremera
	Acacia hockii	Umugenge
	Acacia sieberiana	Umunyinya
	Erythrina abyssinica	Umurinzi

Annex 3.10: List of floristic species at Iyalanda site.

Types of vegetation	Scientific name	Local name (Kirundi or Kinyarwanda)
Aquatic and semi-aquatic Vegetation	***Floating species***	
	Nymphaea lotus	Irebe
	Nymphaea nouchalli	Irebe
	Utricularia stellaris	
	No floating species	
	Typha domingensis	Umuberanya
	Phragmites mauritianus	Amarenga
	Hydrocotyle ranunculoides	
	Enydra fluctuans	
	Aspilia africana	Icumwa
	Ipomoea rubens	
	Ludwigia stolonifera	
	Ludwigia leptocarpa	
	Vossia cuspidata	Umutete
	Echinochloa pyramidalis	
	Commelina diffusa	Uruteza
Vegetation of fallow in flooded zone	***Aquatic and semi-aquatic Vegetation***	
	Cyperus dives	
	Polygonum pulchrum	
	Polygonum strigosum	
	Enydra fluctuans	
	Spilanthes mauritiana,	
	Sphaeranthus suaveolens	
	Hydrocotyle ranunculoides	
	Azolla pinnatta,	
	Lemna rwandensis	
	Panicum subalbidum	Urukeci

Vegetation in agriculture zone on slope	*Spirodela polyrhiza*	
	Cyperus longibracteatus var. *longibracteatus*	
	Cyperus latifolius	
	Ruderal species	
	Bidens pilosa	
	Commelina benghalensis	
	Ageratum conyzoides	
	Bidens pilosa	Icanda
	Planted species	
	Markhamia lutea	Umusave
	Ficus vallis-choudae	
	Ruderal species	
	Bidens pilosa	Icanda
	Ageratum conyzoides	
	Tagetes minuta	
	Achyranthes aspera	
	Asystasia gangetica	
	Galinsoga parviflora	
	Eleusine indica	
	Conyza sumatrensis	
	Abutilon mauritianum	
	Cardiospermum halicacabum	
	Thunbergia alata	
Vegetation of the thickets in the valley	*Grewia mollis*	
	Grewia similis	
	Allophylus africana	
	Rhoicissus tridentata	
	Hippocratea africana	
	Phoenix reclinata	
	Capparis fascicularis	
	Sarcostemma viminale	
	Cissus oliveri	
	Sansevieria dawei	
	Aloe bukobana	
	Lantana camara	
	Ziziphus micronata	
	Asparagus falcatus	
	Cynanchum validum	
	Teclea nobilis	
	Maerua angolense	

Annex 3.11: List of floristic species at Mugombwe site.

Types of vegetation	Scientific Name	Local Name (Kirundi or Kinyarwanda)
Vegetation in buffer zone	***Wetlandland species***	
	Cyperus papyrus	Urufunzo
	Cyperus dives	Ikigaga
	Cyperus latifolius	Urukangaga
	Ipomoea rubens	Inkoba
	Aspilia africana	(Icumwa) Icyumwa

	Hydrocotyle ranunculoides	
	Enydra fluctuans	
	Ludwigia leptocarpa	
	Ludwigia stolonifera	
	Cyperus longibracteatus var. longibracteatus	Umushimboshimbo
	Species in agriculture zones	
	Polygonum pulchrum	Igorogonzi
	Polygonum strigosum	Igorogonzi
	Pycreus capillifolius	
	Echinochloa colona	
	Panicum maximum	
	Cyperus dives	Ikigaga
	Bidens pilosa	
	Eragrostis sp.	
	Cyperus longibracteatus var. *longibracteatus*	
	Agrocharis incognita	
	Commelina benghalensis	Inteza
	Ageratum conyzoides	Akarura
Vegetation on slopes	***Ruderal species in banana plantation***	
	Bidens pilosa	Icanda
	Oxygonum sinuatum	
	Ageratum conyzoides	
	Panicum maximum	Igikaranka
	Oldenlandia herbacea	
	Spermacoce princecae	
	Aerva lanata	Akamongo
	Galisonga parviflora	
	Tagetes minuta	
	Tribulus terrestris	
	Savannah species	
	Parinari curatellifolia	Umunazi
	Combretum molle	Umurama
	Combretum collinum	Umukoyoyo
	Ozoroa reticulata	
	Albizia adianthifolia	Umusebeya
	Albizia versicolour	Umububa
	Uvaria angolensis	
	Haplocoelum gallaense	Umujwiri
	Dalbergia nitidula	Umuyigi
	Melinis minutiflora	Ikinyamavuta
	Maytenus heterophylla	
	Canthium schimperanum	
	Securidaca longededunculata	
	Dovyalis macrocalyx	Umushubi
	Landolphia kirkii	

	Strychnos lucens	Umukome
	Pittosporum spathicalyx	Umunyerezankende
	Acokanthera schimperi	Umusagwe
	Lannea schimperi	
	Canthium lactescens	
	Ochna schweinfurthii	
	Vernonia perrottetii	

Annex 3.12: Floristic species of xerophilous thickets at Gasenyi site.

Types of vegetation	Scientific Name	Local Name (Kirundi or Kinyarwanda)
Large trees of thickets	*Euphorbia candelabrum*	Igihahe
	Pappea capensis	
	Lannea schimperi	Umumuna
Shrubby and climbing lianas	*Acacia hockii*	Umugenge
	Acalypha cf. *bipartita*	Ingesegese
	Acokanthera schimperi	Umusagwe
	Albizia adianthifolia	Umusebeyi
	Albizia versicolour	Umububa
	Apodytes dimitiata	Umusivya
	Caesalpinia decapetala	Umubambangwe
	Canthium schimperanum	Umukiragi
	Canthium sp.	
	Capparis erythrocarpus	Uruzira
	Capparis fascicularis	Uruzira
	Carissa spinarum	Umunyonza
	Cissus oliveri	Umugobore
	Clausena anisata	Umutana
	Clerodendrum myricoïdes	Umunywamazi
	Clerodendrum rotundifolium	
	Combretum collinum	Umukoyoyo
	Combretum molle	Umurama
	Commiphora africana	Umudahwera
	Crabbea velutina	
	Dalbergia nitidula	Umuyigi
	Dichrostachys cinerea	Umukamba
	Dodonea angustifolia	Umusasa
	Entada abyssinica	Umusange
	Erythroccoca bongensis	Umutinti
	Euclea racemosa subsp. *schimperi*	Umucikiri
	Euphorbia candelabrum	Igihahe
	Gardenia imperialis	Umugondo
	Gardenia ternifolia subsp. *jovis-tonantis*	Umuterama
	Grewia mollis	Umugeregere
	Grewia similis	Umukoma
	Haplocoelum gallaense	Umujwiri
	Jasminum dichotomum	

	Landolphia kirkii	Umubungobungo
	Lannea schimperi	Umumuna
	Maytenus arbutifolia	Umugunguma
	Maytenus heterophylla	Umugunguma
	Maytenus senegalensis	Umweza
	Olea europea subsp. *cuspidata*	Umunzenze
	Osyris quadripartita Decn.	Umuvyi
	Ozoroa reticulata	Umukerenki
	Pavetta assimilis	
	Pittosporum spathicalyx	Umunyerezankende
	Rhus longipes	Umusagara
	Rhynchosia resinosa	
	Rytigynia monanta	
	Sarcostemma viminale	Umunyari w'ishamba
	Schrebera alata	Umubanga
	Scutia myrtina	Umugasa
	Flueggea virosa	Umubwirwa
	Senecio hadiensis	Icegera
	Strychnos innocua	Amahonyo
	Strychnos lucens	Amahonyo
	Strychnos spinosa	Umukome
	Teclea nobilis	Umuzo
	Ximenia caffra	Amasasa
	Zanthoxyllum chalybeum	Igugu
	Ziziphus mucronata	Umukugutu
Species in the Underwood of thickets	*Aerva lanata*	
	Aloe bukobana	Inkakarubanmba
	Aloe macrosiphon	
	Asparagus flagellaris	Umunsabe
	Caraluma schweinfurthii	
	Chlorophytum sparsiflorum	
	Commelina elgonensis	Ikiteja
	Orchidaceae (indet.)	-
	Sansevieria dawei	
	Sansevieria cylindrica	

Herbaceous between the thickets	*Panicum maximum*	Igikaranka
	Themeda triandra	
	Hyparrhenia filipendula	
	Sida alba	
	Phyllantus odontadenius	
	Oxygonum sinuatum	Agahandanzovu
	Indigofera zenkeri	
	Indigofera arrecta	Umusorora
	Indigofera sp.	Umusorora
	Desmodium salicifolium var. densiflorum	
	Senna occidentalis	Umuyokayoka
	Hibiscus diversifolia	Umukururantama

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Chapter Four

Chapter Four

Invertebrates of Lake Cyohoha Sub-Basin

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4.0 Introduction

This study was undertaken between November 2007 and March 2008 as part of a multi-disciplinary investigation into wetland biodiversity and water quality assessment in the Cyohoha South Sub-Basin. Primarily, the study was aimed at assessing stock of the invertebrates in the terrestrial area, wetlands, rivers and lakes, and their ecological and economic roles in the sub-basin.

A list of invertebrates was compiled based on field work using various sampling techniques in seven eco-sites. It includes various members of Insecta (12 orders), Araneae, Acarina, Annelida (Oligochaete and Hirudinea), Mollusca and Myriapoda. Through questionnaire administration, the invertebrates readily known and those most liked by people were identified to provide a better understanding to guide the exploration of the invertebrates to support livelihood. Recommendations for management were made, based on three categories of invertebrates, namely, (I) invertebrates with beneficial roles to man, (II) invertebrates with both beneficial and harmful roles to man, and (III) invertebrates with harmful roles to man.

Some of the invertebrate-related livelihood actions recommended for immediate consideration in the Cyohoha South Sub-Basin are: bee farming (apiculture), silkworm farming (sericulture), butterfly farming, eco-tourism, export of beetles, and research and conservation. Development of Environmental Health Indicators for the Lake Cyohoha Sub-Basin was also recommended.

The Nile Transboundary Environment Action Project (NTEAP) undertook in-depth water quality, ecological and socio-economic studies in the Cyohoha South Bub-Basin to generate baseline scientific information needed for future investment in the sub-basin through wise use of the water resources, proper management of wetland areas and biodiversity conservation. Among those studies, the invertebrate's component would come up with a compiled list of invertebrates existing in the sub-basin, take stock of their ecological and economic roles and identify the invertebrates readily known and those most liked by the people.

It is presumably known that invertebrates play important modulating roles in ecosystems at both micro and macro-levels, in the aquatic, terrestrial, arboreal, and the subterranean settings. For, example, Chironomids constitute part of the food chain in food production, and earthworms contribute to litter transformation and ecosystem engineering (Toyota *et l.*, 200*6*). Furthermore, invertebrates are major sources of income, for example, sericulture and apiculture (Raina *et al.*, 1999, 2000) and butterfly farming (Mukandoli Una, 2008); and food directly, for example, *Ruspolia diferens* the "nsenene" (Kaddu *et al.,* 1999).

Modern people utilise invertebrates as environmental indicators; and now in the climate change process, invertebrates (the dung beetles) are implicated in the contribution to the emission reduction of Greenhouse Gases that lead to global warming (Perry, 2007). Furthermore, the harm caused by invertebrates, such as transmission of disease-causing organisms by mosquitoes is well documented. It follows from this that an understanding and appreciation of the ecological and economic roles of invertebrate fauna in any macro-ecosystem such as Cyohoha South Sub-Basin which is composed of several small lakes, rivers and periodical flooding wetlands, and harbors a rich biodiversity is pivotal in designing strategies for socio-economic development and biodiversity conservation.

4.1 Methods used

FIGURE 4.1: Collecting aquatic invertebrates along one of the arms of Lake Cyohoha near Ngenda.

4.1.1 Literature review

Literature was reviewed through visits to various institutions, namely, the National University of Rwanda (Central Library, Faculty of Agronomy Library, Bibliothèque Centrale de l'I.S.A.R.-Rubona, Rwanda), and contacts with various scientist in both Burundi and Rwanda for hard and soft copies of relevant literature.

The invertebrates of Lake Cyohoha have been investigated to some extent by various people previously: Ntakimazi (1985) investigating the hydrobiology of Bugesera found the following zooplanktons: Copepods (*Tuermocyclops ohlangalis* SARS, *Mesocyclops aequatorialis* KIEFER, *Thermocyclops edwardensis* KIEFR, *Eucyclops acantoides);* Cladocera: (*Moins micrura* KURTZ, *Ceriodophnia cornata rigandi* SARS, *Diaphanosoma acisum* SARS); Rotifer: (*Monotoma sp., Polyathra dolicoptera* IDERSON, *Trichocerca sp. ,Lecane cfr. bulla* GOSSE, *Asplanchna brightwelli* GOSSE, *Epiphane (Notops): Macrurus* BARR & DAD, *Brachionus angularis* GROSSE, *Brachionus calyciflorus* PALLAS, *Brachionus caudatus* BARR & DAD, *Brachionus falcatus* ZACHARIAS, *Keratella valga* EHRBS, *Trematrix opoliensis* ZACH, *Rotaria neptunia* EHRBG). The distribution and abundance of the Zooplanktons varies depending on time of the year and the locality. Information from the library at NUR showed that there were 80 publications reflecting on the insects of Rwanda.

Documentary evidence from the I.R.S.T. showed a wide range of literature on invertebrates of Africa including Central Africa and occasional reference to Rwanda and Burundi. The bulk of the documented work was on systematics, and a little on ecology.

Hegh (1922) gave a description of the termites of East Africa, their social structure, biology and diet. A series of publications by Basilewsky (1953, 1955, 1956 and 1957)

Listed collections of the following orders of invertebrates from Central Africa: Collembola, Heteroptera, Thysanura, Odonata, Hemiptera, Mallophaga, Heteroptera, Homoptera, Coleoptera, Embioptera, Mantodea, Lepidoptera, Diptera, Homoptera and Hymenoptera. Spiders of the families Erigonidae and Linyphilidae from East and Central Africa were documented by Ake Holm (1968). Recently, in a three-month undergraduate degree project in the Department of Biology of the NUR Hategekimana (2007) captured the following butterfly families in the arboretum of Ruhanda: Acraidae, Danaidae, Hesperiidae, Lycaenidae, Nymphalidae, Pieridaea and Satyridae

4.1.2 Selection of study sites and features of the eco-sites

The selection of the study sites was undertaken in the following seven eco-sites selected by consensus with other experts carrying out this study: Rugarama, Kagenge, Ngenda, Iyalanda, Marembo, Gasenyi and Muyebe (FIGURE 4.1). The geographical location of the eco-sites is indicated in TABLE 4.1.

FIGURE 4.1: Lake Cyohoha Sub-Basin study sites (square bullets) (not on scale)

TABLE 4.2: Location and duration of work at the various eco-sites

Eco-site Plus Date (of November, 2007) & Duration (hrs)	GPS Data		
	Alt (metres)	S	E
RUGARAMA 21st, 4 hours	1355	02.34564	030.03103
NGENDA 22nd & 23rd, 8 hours	1356	02.32931	029.98891
KAGENGE 24rd & 25th (total 7 hrs), 26th (questionnaire administration)	1361	02.39292	030.07021
Iyalanda 28th, 4 hrs	1357	02.51068	030.12255
GASENYI 29th, 4 hrs	1439	02.37204	030.22048
MAREMBO 29th, 1 hr	1355	02.45380	030.17061
MUYEBE 30th, 2 hrs	1353	02.36319	029.94603

The seven eco-sites were categorised into seven sections as follows;

4.1.2.1 Lower Catchment (Eastern Lake Cyohoha Sub-Basin)

The eco-sites were: Marembo (altitude: 1,355m) and Iyalanda (altitude: 1,357m). There were some cultivated plants, namely, bananas, beans and maize. There were people collecting water throughout the day. The sampling methods were: sweep net, hand-catching, aspirator; Berlese Funnel (at Iyalanda) and soil scope from 1m^2 quadrate. Samples were collected 50m from the lake.

4.1.2.2 Lower Catchment (Middle Lake Cyohoha Sub-Basin)

The eco-sites were: Kagenge (altitude: 1,361m) and Rugarama (altitude: 1,355m). There were trees planted in the 50m buffer zone, and these included: *Cassia spectabilis, Markhamia lutea, Casualina, Cedrella, Grevellia, Carriandra, and Sesbania.* The naturally occurring vegetation in the buffer zone was composed of small trees, *Clerodendrum onyccoids*, (attracting large and small beetles), shrubs, and *Indigofera* (attracting large and small beetles). Some cultivation of seasonal crops was taking place within the buffer zone, and the cultivated crops include: beans, maize (*Zea maise*), tomatoes, and cabbage. The crops were for commercial purposes. There was evidence of use of pesticide(s) on tomatoes to control infestations/infections. There were people, both young and grown up, carrying out various activities, namely, fishing, collecting water, washing clothes and bathing throughout the day. There was human faeces scattered in the sloppy buffer zone, and hence washed down into the lake. The methods of sampling were: sweep net, hand-catching, aspirator, Berlese Funnel and quadrat.

4.1.2.3 Wetland (Western Lake Cyohoha Sub-Basin)

The eco-site was Muyebe (in Mugombwa sector) (altitude: 1,353m) in the western part of the Lake Cyohoha Sub-Basin, in a large expanse of wetland with typical wetland plants, such as papyrus; and many flowering plants attracting butterflies and bees. Akanyaru River flows through the wetland and causes seasonal flooding. A variety of food crops are cultivated adjacent to the wetland; and cattle graze within the wetland. The methods of sampling were: sweep net, hand-catching, aspirator and Berlese Funnel.

4.1.2.4 Lower Catchment (Western Lake Cyohoha Sub-Basin)

The eco-site was Ngenda (in Nyarugenge sector) (altitude: 1,356m) in the western part of the Lake Cyohoha Sub-Basin. There were trees planted in the 50m buffer zone, namely, *Markhamia*, *Casualina*, *Gravellia*, and *Cedrella*. Some cultivation of seasonal crops was taking place between the trees in the buffer zone; and the crops included beans, maize (*Zea maise*), tomatoes, cabbage and rice. Rice cultivation was in a 5-metre belt between the lake water level and the buffer zone. There were people throughout the day carrying out various activities, namely fishing, collecting water, washing clothes and bathing. Human faeces was scattered in the buffer zone. Sampling was carried out using sweep net, hand-catching, aspirator; Berlese Funnel and quadrate.

4.1.2.5 Lake Ecotone Habitat

The Lake Ecotone habitat was a cross-cutting habitat composed of mash. It was a meeting place for the aquatic (e.g. fish, insects, amphibians and snakes), semi-aquatic (amphibians) and terrestrial (humans, insects) biodiversity. Flora in the Lake Ecotone included both mash plants (such as Cyperus papyrus, Phragmites and Typha) and terrestrial ones. Sampling was carried out using: aquatic insect net, hand-catching and scoping.

4.1.2.6 Subterranean (Below Ground Biodiversity)

The eco-sites were: Western Lake Cyohoha Sub-Basin: Ngenda (altitude: 1,356m); Middle Lake Cyohoha Sub-Basin: Rugarama (altitude: 1,355m) and Kagenge (altitude: 1,361m); Eastern Lake Cyohoha Sub-Basin: Iyalanda (altitude: 1,357m) and Gasenyi (altitude: 1,439m). Sampling was within the buffer zone where it existed, and the sampling methods were: soil scoping (about 1kg) from 1m2 quadrate, hand-catching, and Berlese Funnel. Sample of soil scope was preserved for laboratory examination both in 70% ethanol and in specimen polybags without alcohol to allow biological activity. Berlese Funnel of soil-dwelling arthropods; sample preserved for laboratory examination

4.1.3 General Sampling Methods and routines

Equipment for terrestrial-based invertebrates collections, sweep nets and aspirators were borrowed from Makerere University Kampala. Sampling was by sweep net, hand catching, aspirator, quadrate, scoping, modified Berlese Funnel partly as described by Mbata (1997).

Samples, we transported from the eco-site to the field station (Ruhuha or Kirundo) daily. They were analysed and sorted out into various taxa at the field station. Samples requiring microscopy were preserved until return to Kigali where they were analysed at Laboratoire de la qualité de l'eau (NUR). Samples of invertebrates were photographed either at eco-site or at the field station (see Photo 4.1).

4.1.3.1 Questionnaire administration and personal contacts with key people

A cross-section of people in the study area was interviewed using a structured questionnaire. This activity was carried out only in Ruhuha Sector owing to time limitation.

4.2 Results

4.2.1 Invertebrates found

The invertebrates collected from various eco-sites are indicated in Tables 4.2 to 4.8 and selected photographs some of which are habitat related shown in Appendix 4.1 and 4.2

Lepidoptera : Moth from Rugarama

Lepidoptera: Butterfly *(Acraea acerata)* from Rugarama

Coleoptera: Longhorn beetle (*Macrotoma*) from Iyalanda

PHOTO 4.1: Samples of the invertebrates collected from various Ecosites in the Cyohoha Sub-basin

TABLE 4. 2: Terrestrial and subterranean* invertebrates from the upper catchment of Eastern Lake Cyohoha Sub-Basin: Gasenyi Eco-site

Order/ Suborder	Q	Family	Q	Genus / Sp.	Econ. Import.	Eng. name	**Local name (Kn)**	**(Kd)**
Lepidoptera	2	Nymphalidae	2	*Acraea acerata*	Pollinator, Potato pest	Butterfly	Ikinyu-Gunyugu	Ikinyu-gunyugu
Phasmatodea	1	Heteronemiidae		*Phalces*	No doc.	Stick insect		
Diptera	1	Calliphoridae	1	*Lucilia*	Ecto-parasite	Blow fly		
Hymenoptera	4	Apidae	4	*Apis*	Pollinator	Honey bee	Uruyuki	Uruyuki
Hymenoptera	6	Formicidae	6	*Myrmicaria*	Scavengers, cleaners	Drop-tail ant		
Diptera	2	Calliphoridae	2	*Chrysomya*	Eats cadaver	Filth fly		
Hemiptera	1	Pentatomidae	1	Veterna	No doc.	Grass stink bug		Igifushi
Hemiptera	2	Alydidae	2	Nariscus	No doc.	Broad-headed bug		
Hemiptera	3	Sercopidae	3	Unidentified	Plant pest	Frog hopper		
Blattodea	2	Blatellidae		*Blatella*	Birds' food	Cockroach	Inyenzi	Inyenzi
Acarina	4	Ixodidae	4	Unidentified	Parasite & vector	Hard tick	Ikirondwe	
Lepidoptera	1	Unidentified	1	Unidentified	Pollinator	Butterfly	Ikinyu-gunyugu	Ikinyu-gunyugu
Orthoptera	1	Acrididae	1	*Acanthacris*	Birds' food, plant pest	Grasshopper	Isenene	Isenene
Orthoptera	4	Acrididae	4	*Rhachitopis*	Birds' food, plant pest	Grasshopper	Isenene	Isenene
Orthoptera	2	Acrididae	2	*Paracinema*	Birds' food, plant pest	Grasshopper	Isenene	Isenene
Coleoptera	1	Staphylinidae	1	*Paederus*	Causes skin rush	Nairobi fly	Nyamuca	Nyamuca
Coleoptera	3	Scarabaeidae	3	*Kheper*	Cleaner	Dung beetle		Ikiyinga
Coleoptera	4	Meloidae	4	*Decapotoma lunata*	Feeds on flowers	Blister beetle		
Coleoptera	4	Discolomatidae	4	*Notiophygus*	No doc.	Beetle		
Coleoptera	7	Coccinellidae	7	Unidentified	Plant pest	Beetle		

Coleoptera	1	Hydrophilidae	1	*Hydrophilus*	Scavenger, cleaner	Scavenger beetle		
Coleoptera	3	Unidentified	3	Unidentified	No doc.	Beetle		
Isoptera*	15	Termitidae	15	*Odontotermes*	Animal food, pest	Termite	Inswa	Inyabobo
Hymenoptera	10	Unidentified	10	Unidentified	Scavenger	Ant	Inshishi	Utun-yegeri
Hymenoptera	8	Formicidae		*Anoplolepis*	Scavenger	Ant	Ikimonyo	
Mantodea	1	Mantidae	1	*Ligariella*	Bio control	Ground mantids	Igitam-bara	Intengasi
Araneae	3	Theraphosidae	3	Unidentified	Bio cont	Tarantula	Igitagan-gurirwa	Igitangu-rirwa

TABLE 4.3: Terrestrial and subterranean* invertebrates from the lower catchments of Eastern Lake Cyohoha Sub-Basin: Marembo Eco-site

Order/ Suborder	Q	Family	Q	Genus / sp.	Econ. Import	Eng. name	Local name **(Kn)**	**(Kd)**
Hymenoptera	1	Formicidae	1	*Myrmicaria*	Scavenger	Ant	Inshishi	Utunye-Geri
Lepidoptera	2	Nymphalidae	2	*Acraea acerata*	Pollinator, plant pest	Sweet potato butterfly	Ikinyu-gunyugu	Ikinyu-gunyugu
Lepidoptera	1	Nymphalidae	1	*Junonia oenone*	Pollinator, plant pest	Butterfly	Ikinyu-gunyugu	Ikinyu-gunyugu
Orthoptera	2	Acrididae	2	*Acrida*	Birds' food	Common stick/ Grasshopper	Isenene	Isenene
Orthoptera	2	Acrididae	2	*Acanthacris*	Birds' food	Garden locust	Igihore	Igihori
Orthoptera	1	Tettigonidae	1	*Ruspolia*	Birds' food	Eatable/ Grasshopper	Isenene	Isenene
Araneae	1	Unidentfied	1	Unidentfied	Bio. control	Spider	Igitaga-ngurirwa	Igitangu-Rirwa

TABLE 4.4: Terrestrial and subterranean* invertebrates from the lower catchments of Eastern Lake Cyohoha Sub-Basin: Iyalanda Eco-site

Order/ Suborder	Q	Family	Q	Genus / Sp.	Econ. Import	Eng. Name	Local name **(Kn)**	**(Kd)**
Hemiptera	1	Lophopidae	1	*Elasmoscelis*	No doc.			
Hemiptera	1	Nepidae	1	*Laccotrephes*	Bio control	Common water scorpion		
Hemiptera	2	Pentatomidae	2	*Veterna*	No doc.	Grass stink bug		
Hemiptera	5	Alydidae	5	*Nariscus*	No doc.	Bug		
Orthoptera	5	Tettigonidae	5	*Ruspolia*	Animal food & people	Eatable Grasshopper	Isenene	Isenene
Orthoptera	9	Gryllidae	9	*Platygryllus*	Birds' food	Cricket	Ijeri	Umujo-gojogo
Coleoptera	1	Dytiscidae	1	*Cybister*	Bio contol	Water beetle	Inyogaruzi	
Coleoptera	2	Unidentified	2	Unidentified	No doc	Beetle	Ikivumvuri	
Coleoptera	1	Scarabaeidae	1	*Aphodius*	Scavenger	Miniature dung chafer		
Hymenoptera	5	Apidae	5	*Apis*	Pollinator, food, Medicine	Honey bee	Uruyuki	Uruyuki
Hymenoptera	6	Formicidae	6	Myrmicaria	Scavenger	Ant	Inshishi	Utunyegeri
Hymenoptera	2	Formicidae	2	*Lepisiota*	Household pest	Sugar ant		

Isoptera	6	Hodotermitidae	6	Unidentified	fish food& people	Termite	Inswa	Inyabobo
Odonata	1	Libellulidae	1	*Brachythemis*	Bio control	Dragon fly		
Lepidoptera	1	Nymphalidae		*Acraea encedon*	Pollinator, plant pest	Butterfly	Ikinyu-gunyugu	Ikinyu-Gunyugu
Blattodea	11	Blatellidae	11	*Blatella*	Pest	small cockroach	Inyenzi	Inyenzi
Araneae	3	Unidentified	3	Unidentified	Bio control	Spider	Igitaga-ngurirwa	Igita-ngurirwa
Myriapoda / Spirobolida	2	Luliformia	2	Unidentified	Food for centipede, spiders, predatory insects	Spirobolid millipede	Muhuhezi or Mukondo-winyana	Inyongori
Collembola	1							
Rhabditida	8			Strongyloides				

TABLE 4.5: Terrestrial and subterranean* invertebrates from the lower catchments of Middle Lake Cyohoha Sub-Basin: Kagenge Eco-site

Order /Taxon	Q	Family	Q	Genus/ Sp.	Econ. import.	Eng. Name	Local name (Kn)	(Kd)
Coleoptera	1	Scara-baeidae	2	*Mecynorrhina*	Market **TABLE**	Orange-spotted Fruit chafer	Ikivumvuri	
Coleoptera	1		1	*Chlorocala*	Market **TABLE**	"Four-spotted brown-green chafer"		
Coleoptera	18		18					
Orthoptera	1		1					
Orthoptera	17	Acrididae	17		Food for animals	Short-horned grasshopper	Isenene	Isenene
Orthoptera	9	Pyrgomor morphidae	9	*Zonocerus variegates*	Plant Pest	Elegant grasshopper	Isenene	Isenene
Odonata	2		2			Dragon fry	Umu-nzereri	Umu-Nzereri
Blattodea	2		2		Animal food	Cockroach	Inyenzi	Inyenzi
Hemiptera	2	Gerridae	2	*Lymnogonus*	No doc	Striped pond skater		
Hemiptera	3							
Hymenoptera	3	Penta-nomidae	3	Caura		Stink bugs, Sield bugs		
Lepidoptera	5					Butterfly	Ikinyu-gunyugu	Ikinyu-Gunyugu
Lepidoptera	1	Cossidae	1	*Macrocossus*	Silk, plant pest	Moth	Ikinyu-gunyugu	Ikinyu-Gunyugu
Diptera	1							
Diptera	15	Chiro-nomidae	15		Food for fish	Midges, lake fly		
Araneae	1		1			Spider	Igitaga-ngurirwa	Igita-Ngurirwa
Myriapoda	1		1			Spirobolid millipede		

Oligochaeta	9		9	*Lumbricus*	Food for fish	Earthworm		
Gnathobdellidae	2		2	*Hirudo medicinalis*	Ectoparasite	Leech		

TABLE 4.6: Terrestrial and subterranean* invertebrates from the lower catchments of Middle Lake Cyohoha Sub-Basin: Rugarama Eco-site (in Ruhuha Sector)

Order/ Suborder	Q	Family	Q	**Genus/sp.**	**Econ. import.**	**English name**	**Local name**	
							(Kn)	**Kd)**
Orthoptera	1	Acrididae	1	*Acanthacris*	Birds' food	Garden grasshoper	Igihore	Igihori
Orthoptera	6	Tettigonidae	6	Ruspolia	Birds' food, people, fish			
Orthoptera	2	Acrididae	2	*Acrotylus*	Birds' food, fish	Grasshoper	Isenene	Isenene
Coleoptera	5	Coccinellidae	5	No doc.	Plant pest	Ladybirds beetles		
Coleoptera	3	Hydrophilidae	3	*Hydrophilus*	No doc.	Water scavenger beetle		
Coleoptera	2	Gryllidae	2	*Platygryllus*	Birds' food	Cricket	Ijeri	Umujo-Gojogo
Coleoptera	12		12		Ornamental, tourism, expt			
Coleoptera	1	Scarabidae	1	*Diplognatha*	Plant pest	Large black chafer	Ikivu-Mvuri	Ikivu-Mvuri
Lepidoptera	2	Pieridae	2			Butterfly	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Lepidoptera	2		2		silk, pollinator, feed,pest,biol.	Moth	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Hymenoptera	6	Apidae	6	*Apis*	Honey, pollinator	honey bee	Uruyuki	Uruyuki
Hymenoptera	4	Formicidae	4	*Myrmicicaria*	scavengers, cleaners	Ant	Inshishi	Utunye-geri
Hemiptera	4	psyllidae	4	*Retroacizzia*	Plant pest	Plant bug		
Hemiptera	3	Discolomatidae	3	*Notiophygus*	No doc.	Beetles		
Hemiptera	1	Aradidae	1	*Strigocoris*	No doc.	Bugs		
Mecoptera	2	Tipulidae	2	*Nephrotoma*	No doc.	hanging fly		
Diptera	1	Chironomidae	1	*Chironomus?*	food for fish	Midges, lake fly		
Blattodea	2	Blattidae	2		Birds' food Sanitation	Cockroach	Inyenzi	Inyenzi
Araneae	1	unidentified	1	Unidentified	Bio control	Spider	Igitaga-Ngurirwa	Igita-Ngurirwa

TABLE 4.7: Terrestrial and subterranean* invertebrates from the lower catchments of Western Lake Cyohoha Sub-Basin: Ngenda Eco-site (in Nyarugenge Sector)

Order/ Suborder	Q	Family	Q	Genus / Sp.	Econ. Import.	Eng. Name	**Local name**	
							(Kn)	**(Kd)**
Coleoptera	2	Cerambycidae	1	*Macrotoma palmate*	No doc.	Large brown longhorn beetle	Ikivumvuri	

Coleoptera	1	Cerambycidae	1	*Prionorhinus*	Pests of plants			
Coleoptera	10	Coccinellidae	10	Unidentified	Pests of plants	Lady birds, Lady bugs		
Coleoptera	9	Scarabaeidae	9	*Aphodius*	No doc.	Beetles	Ikivumvuri	
Coleoptera	1	Carabidae	1	*Caminara*	No doc.	Starred ground beetle	Ikivumvuri	
Coleoptera	1	Unidentified	1	Unidentified	No doc.	Beetle	Ikivumvuri	
Coleoptera	1	Chrysomelidae	1	*Basipta*	Pest of plants	Green tortoise beetle	Ikivumvuri	
Coleoptera	7	Unidentified				Beetle	Ikivumvuri	
Siphonaptera	1	Pulicidae	1	*Xenopsylla*	transmit disease	Rat flea	Imbaragasa	
Blatodea	1	Blatteridae	1	*Blatella germanica*	No doc.	German cockroach	Inyenzi	Inyenzi
Hemiptera	1	Nepidae	1	*Laccotrephes*	Bio Control	Common water scorpion		
Hemiptera	8	Pentatomidae	8	*Pentatoma*	Pests of plants	Shield bugs, stink bugs		
Hemiptera	36	Alydidae	36	*Neriscus*	Pests of plants	Bug		
Hemiptera	1	Pyrrhocoridae	1	*Dysdercus*	Pest of cotton	Cotton stainer		
Hemiptera	1	Ochteridae	1	*Ochterus*	No doc.	Shore bug		
Hemiptera	1	Aradidae	1	*Strigocoris*	Feeds on fungi	Bark bug		
Hemiptera	2	unidentified	2	Unidentified	No doc.	Bug		
Lepidoptera	1	Nymphalidae	1	*Junonia oenone*	Pollination, pests of plants	Butterfly	Ikinyu-gunyugu	Ikinyu-gunyugu
Lepidoptera	1	Unidentified	1	Unidentified	Pollination, pests of plants	Moth	Ikinyu-gunyugu	Ikinyu-gunyugu
Orthoptera	1	Pyrgomorphidae	1	Zonocerus elegans	No doc.	Elegant Grasshopper	Isenene	Isenene
Orthoptera	2	Acrididae	1	*Acanthacris ruficornis*	Birds' food	Garden Locust	Igihore	Igihori
Orthoptera	1	Acrididae	1	*Acrida*	Birds' food	Stick grasshopper	Isenene	Isenene
Orthoptera	1	Acrididae	1	*Paracinema*	Birds' food, plant pest	Sort-horned grasshopper	Isenene	Isenene
Orthoptera	2	Tettigoniidae	2	*Eurycorypha*	Birds' food, plant pest	Leaf katydid		
Orthoptera	1	Gryllidae	1	*Platygryllus*	Birds' food	Garden cricket	Ijeri	Umujo-gojogo
Orthoptera	1	Acrididae	1	*Rhachitopis*	Birds' food	Grasshopper	Isenene	Isenene
Orthoptera	1	Tettigoniidae	1	*Ruspolia*	Birds' food people	Grasshopper	Isenene	Isenene
Hymenoptera	13	Formicidae	13	*Myrmicaria*	Scavenger	Drop-tail ant	Inshishi	Utunye-geri
Hymenoptera	1	Anthophoridae	1	*Xylocopa caffra*	damages wood	Carpenter bee	Ikivumvuri	
Diptera	2	Athericidae	2	*Suragina*	No doc.	Fly	Isazi	isazi
Araneae	8	Unidentified	8	*Unidentified*	Bio control	Spider	Igitaga-ngurirwa	Igita-Ngurirwa
Prosobra-Nchiata	1	Thiaridae	1	*Thiara granifera*	Vector of helminth	Snail		

Pulmonata	7	Lymnaeidae	7	*Lymnaea*	Vector of helminth	Snail		
Pulmonata	14	Planobidae	14	*Biompha-laria*	Vector of helminth	Snail		
Oligochaeta	4			*Lumbricus*	Food for fish	Earthworm		

TABLE 4.8: Terrestrial and subterranean* invertebrates from the wetland of Lake Cyohoha Sub-Basin: Muyebe Eco-site (in Mugombwa)

Order/ Suborder	Q	Family	Q	Genus / Sp.	Econ Import.	Eng. name	Local name **(Kn)**	**(Kd)**
Hemiptera	1	Coreidae	1	*Holopterna*	No doc.			
Orthoptera	3	Acrididae	3	Orthoctha	Birds' food	Grasshopper	Isenene	Isenene
Orthoptera	1	Gryllidae	1	*Platygryllus*	Birds' food	Garden Cricket	Ijeri	Umujo-Gojogo
Orthoptera	3	Acrididae	3	*Acrida*	Birds' food	Stick Grasshopper	Isenene	Isenene
Orthoptera	1	Tettigo-nidae	1		Birds' food	Katydid		
Orthoptera	4	Acrididae	4	*Paracinema*	Birds' food	Grasshopper	Isenene	Isenene
Hymenoptera	5	Apidae	5	*Apis merifera*	Cottage industry	Honey Bee	Uruyuki	Uruyuki
Hemiptera	9	Cerco-pidae	9	*Ptyelus*	Pest of tree	Rain-tree bug		
Coleoptera	1	Chriso-melidae	1	*Megaleruca*	Plant pest	Leaf beetle		
Coleoptera	5	Chriso-melidae	5		Plant pest	Green tortotoise beetle		
Coleoptera	188	Chriso-melidae	188	*Platycorynus*	Plant pest	Milk weed Leaf Beetle		
Coleoptera	1	Chriso-melidae	1	*Aspidimorpha*	Plant pest	Dune Tortoise Beetle		
Coleoptera	6	Cera-mbycidae	6	*Anubis*	Damage to wood?	Beetle	Ikivu-mvuri	Ikivu-mvuri
Coleoptera	2	Chriso-melidae	2		Plant pest	Tortoise Beetle		
Lepidoptera	3	Nympha-lidae	3	*Acraea encedon*	Pollinator	Brush-footed butterfly	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Lepidoptera	1	Nympha-lidae	1	*Acraea partapalis*	Pollinator	Butterfly	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Lepidoptera	1	Nympha-lidae	1	*Acraea acerata*	Pollinator, pest	Butterfly	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Lepidoptera	1	Pieridae	1	*Belenois*	Pollinator	Butterfly	Ikinyu-Gunyugu	Ikinyu-Gunyugu
Blattodea	1	Blatellidae		*Blatella*	Scavenger	German cockroach	Inyenzi	Inyenzi
Diptera	1	Muscidae		*Stomoxys*	Blood sucker	Stable fly	Isazi	Isazi
Diptera	1	Bibionidae	1	*Bibio*	Pollinator	Fly	Isazi	Isazi
Araneae	1	Unidentif.	1	unidentified	Bio control	Spider	Igitaga-ngurirwa	Igita-Ngurirwa
Hymenoptera	5	Fomicidae	5	*Dorylus dorylini*	Bio control	Safari ant	Intozi	

4.2.2 *Results of microscopic examination of mud grabbed from the lake bottom and soil sampled with modified Berlese Funnel*

One Chironomid larva was found in the mud picked from Bihari, one of the three sampling sites. Nematode *Strongyloides stercoralis* larvae and Collembola were found in soil samples from Iyalanda.

4.2.3 *Results of questionnaire administration*

The following figures show results obtained from questionaires administered during the study.

FIGURE 4.2: Invertebrates liked by people in Lake Cyohoha Sub-Basin

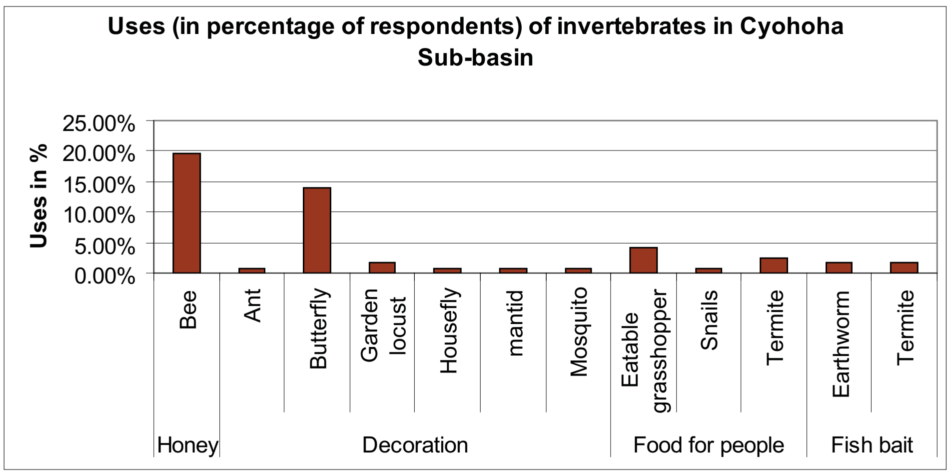

FIGURE 4. 3: Use of various invertebrates in Lake Cyohoha Sub-Basin

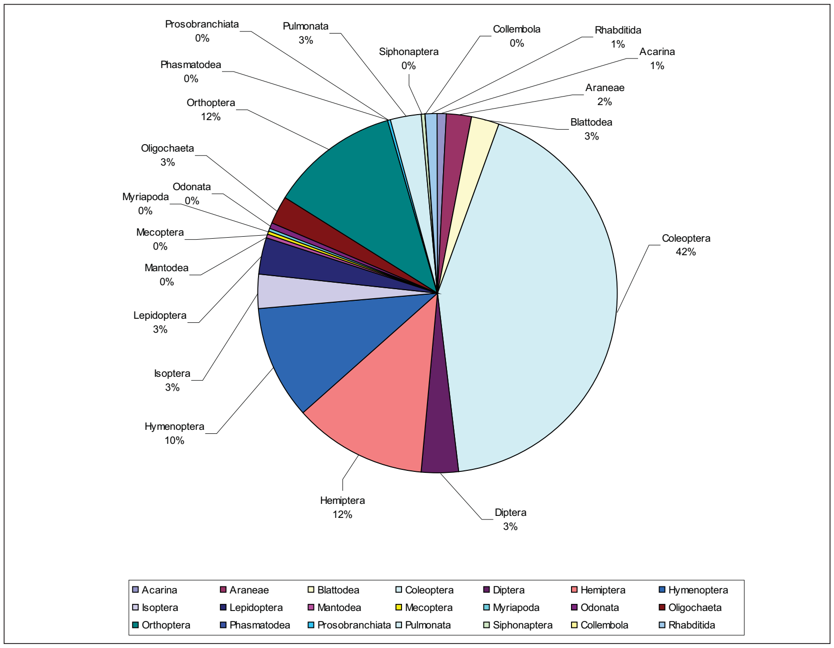

FIGURE 4.4: Invertebrates known by people in Lake Cyohoha Sub-Basin

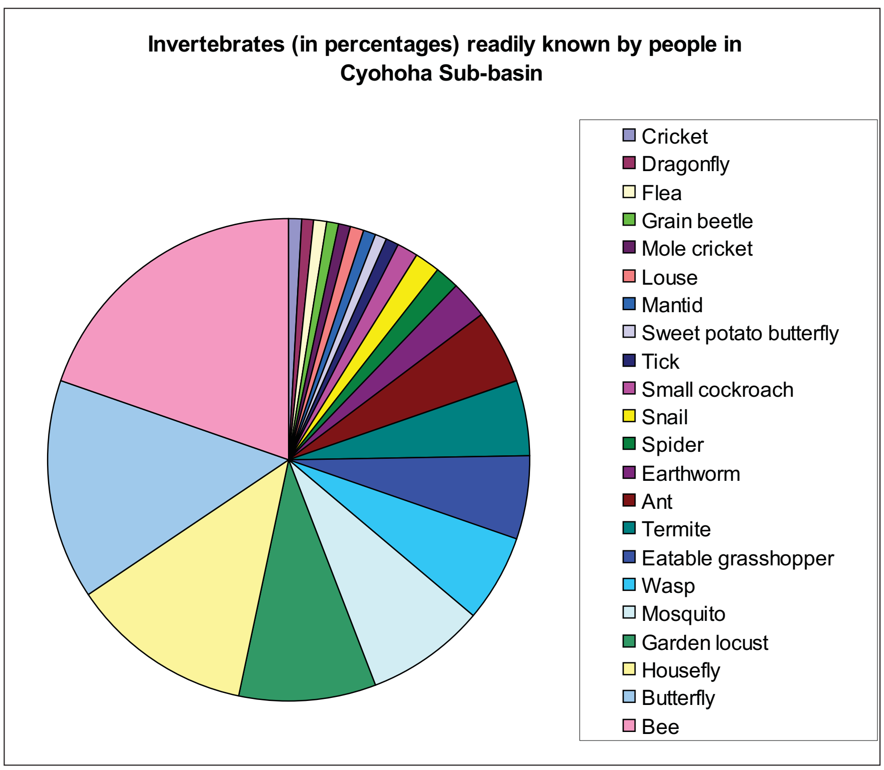

FIGURE 4.5: Prevalence of invertebrates in Lake Cyohoha Sub-Basin. Key: Three invertebrates and below appear as zero in FIGURE. 4.

The most prevalent invertebrate order was Coleoptera (i.e. the beetles, 43%), followed by Orhoptera (i.e. the grasshoppers and allied insects, 12%), Hemiptera (i.e., plant bugs and their allies, 12%), and Hymenoptera (i.e., the bees, wasps and related insects). The less common invertebrates were Collembola, Mantodea, Mecoptera, Myriapoda, Odonata, Phasmatodea, Prosobranchiata, and Siphonaptera. It should be emphasised that the difference in abundance could be partly attributed to the different sampling regimes at the various eco-sites.

4.2.4 Indicator invertebrates of environmental health

It is useful to explain a few terms linked to this topic.

What is environmental health? "Environmental health comprises those aspects of human health and diseases that are influenced by factors in the environment" (Tambling and Slaney, 2007). On the other hand what is an "environmental health indicator (EHI)"? It is "An expression of the link between environment and health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision making" (Tambling and Slaney, 2007). There are some aspects necessary for a potential indicator to be recognised as an EHI, namely, that it should provide information about scientifically based linkage between environment and health; and also that an EHI requires the use of data collected routinely. There was no invertebrate to fit these criteria at the time of the study. Among the potential EHIs in the Lake Cyohoha Sub-Basin are various human infective helminthes, such as, nematodes.

4.3 Linkages of the invertebrates to livelihood opportunities and risks in the Lake Cyohoha South Sub-Basin riparian population and the region

4.3.1 Linkage of invertebrates to livelihood opportunities

From the point of view of livelihood of the Cyohoha riparian population and the region, the invertebrates were put into three categories, namely, (i) invertebrates with beneficial roles, (ii) invertebrates with both beneficial and harmful roles and (iii) invertebrates with harmful roles. Invertebrate-related livelihood activities may be considered in three phases, namely, immediate, medium-term and long-term.

The most logical approach to the immediate invertebrate-related livelihood activities would be to start with the invertebrates known and liked by the communities. For this reason among the invertebrate-related **livelihood activities recommended for immediate consideration** in the Cyohoha South Sub-Basin are: bee farming (**apiculture**), silkworm farming (**sericulture**), and **butterfly farming**. A number of people in Rwanda are showing interest in work on butterflies. A preliminary observation of the upper canopy butterfly fauna of Nyange Forest made by the Catholic University project reported the abundance of the butterfly family known as Papilionidae in the forest (Ruboneka, 2008).

Activities for the medium-term and long-term may include, but not restricted to, aspects such as eco-tourism, export of invertebrates such as beetles, conservation and research to generate data and information.

4.3.2 Linkage of invertebrates to risks

Various invertebrates pose risks in the Lake Cyohoha Sub-Basin. The medicinal leech bites people and animals (see annex). The Staphylid Nairobi fly, *Paederus crebinpunctatus* and *Paederus sabaeus*, produces a toxin, pederin which causes blistering http://en.wikipedia.org/wiki/Nairobi_fly).

4.4 Recommendatons for management based on presence or absence of invertebrates

4.5.1 Bee Farming (Apiculture) as a cottage industry

The people interviewed during questionnaire administration in the present study showed interest in bees. Bees were the most preferred invertebrates (FIGURE 4.2). Some people already have beehives (see Figure 4.6).

Honey is both medicinal and food. It is sold in supermarkets in Kigali, indicating that honey industry is viable in various parts of Rwanda, including Lake Cyohoha Sub-Basin. Bees also provide a source of other products from which people can derive livelihoods, namely bees wax and propolis. Beeswax is naturally produced by young worker bees. It is used in the manufacture of various products, namely, natural skin care products, soaps, hair care products, natural furniture polish and beeswax candles. Propolis is a nutritive natural resin produced by bees. It is antibacterial, antifungal, and anti-inflammatory. It contains most if not all the vitamins and many amino acids as well as minerals. Training programmes will have to be developed through various avenues, such as, NGOs/SBOs/ CSOs, and funds secured from donor agencies, such as the UNDP/SGP.

To be able to undertake bee farming effectively on a large scale, it will be necessary to carry out queen raring so that queen bees are produced in the laboratory and given out to bee keepers. Also the tree planting programmes (highly commendable in Rwanda, but apparently to be strengthened in Burundi) will have to take into consideration the type of trees and shrubs liked by bees.

FIGURE 4.6: Traditional bee farming: a traditional bee hive made out of banana fibres and hang in an avocado tree (Persea americana) at Ngenda Ecosite.

4.5.2 . Sericulture

Mulberry-silk: The farming of moths to produce textiles is in its infancy in Rwanda. There is potential for large scale cottage industry based on sericulture in Rwanda. Already sericulture has started in Rwanda with 10,000 acres of land allocated for production of mulberry plants on which silk moths feed. Silk farms are reported in, Rushashi, Karongi, Nyagahanga and Nyanza (where a factory is under construction Mukandoli Una, 2008). Mulberry is food for not only silk worms but also birds and people. So, introduction of mulberry cultivation will provide multi-faceted contribution to improvement in livelihood.

Non-mulberry silks: While the immediate sericulture activities in the Cyohoha Sub-Basin should focus on mulberry silk secreted by *Bombyx mori*, non-mulberry silks (produced by other insects such as, *Anaphae* silkworm, and *Philosomia ricinus*) has market value (Jolly *et al.*, 1979). *Anaphae* and other insects secreting non-mulberry silks feed on wild trees and shrubs, namely*, Bridelia micrantha*, family Euphobiaceae for *Anaphae* and *Ricinus communis,* also *family* Euphobiaceae, for *Philosomia ricinus.*

This makes non-mulberry silks advantageous to forestry as well as it arrests forest destruction. Introduction of *Philosomia ricinus* is worthy exploring since the Castor oil plant, *Ricinus communis,* thrives well in the Lake Cyohoha Sub-Basin (see Appendix).

Non-insect silks: Apart from insect-based silks, varieties of non-insect silks are known and await exploitation in Africa. These include Spider-silk currently produced commercially from Madagascar spiders species (*Nephila (N. madagascarensis)*, *Mirandtia aurentia* and *Epeira*) and Mussel silk secreted by bivalves (Jolly *et al., 1979).* The farming of moths (insects) to produce textiles is in its infancy in Rwanda. There is potential for large scale cottage industry based on sericulture in Rwanda.

4.5.3. Conservation and research invertebrates of Lake Cyohoha Sub-Basin

Why conservation? Snails are eaten by some birds and they provide a source of calcium used in manufacture of poultry feed. The medicinal leech, *Hirudo medicinalis* has both negative and positive economic importance to man. It is used today to relieve pressure and to restore circulation (Silverstein, 2008; and Artuz, 1990). The medicinal leech is listed as vulnerable by the IUCN and it is protected under schedule 5 of the WCA 1981. Therefore Lake Cyohoha has potential to attract research on *Hirudo* and perhaps become a "leech site".

4.5.4 Develop Environmental Health Indicators (EHI) for Cyohoha

Based on the observed prevalence of nematodes in this study, plus the high prevalence of harmful bacteria (*E. coli*) reported by Gashagaza (2008) it will be useful to undertake projects to develop EHIs which can be used to make health-related decisions in the Lake Cyohoha Sub-Basin.

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Appendices

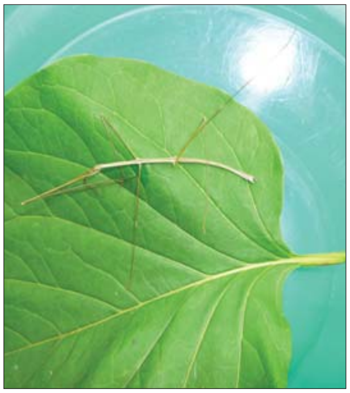
Appendix 4.1: Data Collection

Questionnaire administration at Kagenge

Sampling insects by sweep net at Kagenge

Sampling invertebrates by Hand Picking at Kagenge

Appendix 4.2: Samples of the invertebrates collected from various Ecosites in the Cyohoha Sub-Basin



Phasmatodea: *Stick insect from Rugarama*

Diptera: *Filth fly from Marembo*

Coleoptera: *Nairobi fly (Paederus) from Ngenda*

Coleoptera: *Beetles (Diplognatha gagates) feeding on plant (Indigophera arrecta) at Kagenge*

Coleoptera: *Beetle (Chlorocala africana?) from Kagenge*

Coleoptera: *Beetle from Kagenge*

Coleoptera: *Water beetles (Cybister)*

Hymenoptera: *Carpenter Bee from Kagenge*

Hemiptera: *Water scorpion (Nepidae) from Iyalanda*

Mollusca: *Gastropod snail from Ngenda*

Myriapoda: *Spirobolida: Millipede from Iyalanda*

Mollusca: *Lymnaeidae Snails from Ngenda*

Mollusca: *Planobidae Snails from Ngenda*

Isoptera: Termites at Kagenge

Termites damaging tree root system in the buffer zone at Kagenge.

Acarina: Exodid ticks from Gasenyi

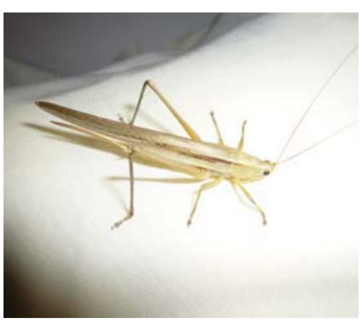
Mantidae: *Praying mantis from Kagenge*

Araneae: Mygalomorpha: *Tarantula spider from Gasenyi*

Mantidae: *Praying mantis cocoon fixed on grass from Iyalanda*

Hemiptera: *Water striders (Tenagovelia?)from Mayebe*

Odonata: *Banded Dragonfly (Brachythemis leucostica?) from Iyalanda*



Orthoptera: *The brown variety of Ruspolia differens, the edible grass hopper, from Kagenge*

Orthoptera: *The green variety of Ruspolia differens, from Kagenge*

Hymenoptera: *A nest (broken up) of wild bees , from Gasenyi*

Orthoptera: *Elegant grasshopper (Zonocerus elegans) from Ngenda*

Aranea: *Spider from Ngenda*

Oligochaete: *Earth worm (Lumbricus terrestris) from Ngenda*

Hirudinea: *A leech (Hirudo medicinalis?) feeding on a fish (Haplachromis burtani) from Kagenge.*

The Castor oil plant Ricinus communis (with large digitate leaves), seen at Ngenda Ecosite, is the favourite food for the non-mulberry silk worm, Philosomia ricinus

Orthoptera: *Dryllidae, Acanthogryllus (Brown cricket) from Kagenge*

Students of Biology at NUR talking to Professor John B. Kaddu (right) in the Biology Department at NUR about invertebrates in the Cyohoha Sub-basin

Leaf beetles: **Chrysomeridae** *(Megaleruca?) feeding on wild plants at Mayebe ecosite.*

Chapter Five

Chapter Five

Fishes of Lake Cyohoha

Gaspard Ntakimazi

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5.0. Introduction

The fisheries section of this study aimed at enhancing the understanding of the role of wetlands as habitats for fish and other biodiversity. During the study, part of the Akagera Basin and the Lake Cyohoha were sampled together with other multi-discplinary teams that consisted of a limnologist, a botanist, an entomologist, a herpetologist, an ornithologist, a mammalogist and a socio-economist. The output of this study is an important tool for awareness campaigns in riparian countries for a better management of the trans-boundary resources. This chapter presents the results of the ichthyology component of the study.

5.1. Objective

The objective of the ichthyology component study was to provide information on fish biology, fish stock and fisheries status in Lake Cyohoha and associated wetlands for use in trans-boundary sustainable management of the fish resources taking into consideration the needs for biodiversity conservation.

The expected output is an assesment of the fisheries of Lake Cyohoha and associated wetlands. The fish biodiversity, ecological structure, stock status, linkage of fisheries to the livelihoods, and a legal and institutional arrangement proposal for the fisheries management are highlighted in this report.

5.2. Method used

The study was conducted through literature review and experimental fishing to get the current situation in fish biodiversity and the fish stocks. Field interviews were carried out to assess the present status and the management of this important socio-economic activity in Lake Cyohoha Sub-Basin both in Burundi and Rwanda.

Literature review

Available documents at at national, provincial and district levels in Burundi and Rwanda were accessed and reviewed.

Experimental fishing

Three (3) sampling stations were selected at the north, in the centre, and in the south of the lake. From each station, samples were taken from the littoral zone and from the pelagic zone. From the southern station, sampling was conducted in a semi-littoral zone as well, in the middle of a calm bay. The pelagic sites at the northern end and the central part of the lake are located at the border between Rwanda and Burundi. The coordinates of these stations and sampling dates are indicated in TABLE 5.1 and in FIGURE 5.1 below.

TABLE 5.1: Coordinates of sampling sites and sampling dates of experimental fishing in Lake Cyohoha in 2007

Stations	Locations	Latitude	Longitude	Sampling date	Sampling time
1	Kiri littoral	2° 20’ 42.55”	29° 59’ 28;37”	28-Nov	day time
	Kiri pelagic	2° 20’ 34;10”	29° 59’ 36.40”	29-Nov	night time
2	Kigina littoral	2° 24’ 09.84”	30° 04’ 14.23”	29-Nov	day time
	Kigina pelagic	2° 23’ 57.35”	30° 04’ 14.23”	30-Nov	night time

3	Iyalanda littoral	2° 29' 11.47"	30° 07' 00.36"	26-Nov	night time
	Iyalanda pelagic	2° 28' 52.80"	30° 07' 18.41"	28-Nov	night time
	Iyalanda bay	2° 30' 16.55"	30° 07' 21.87"	27-Nov	day time

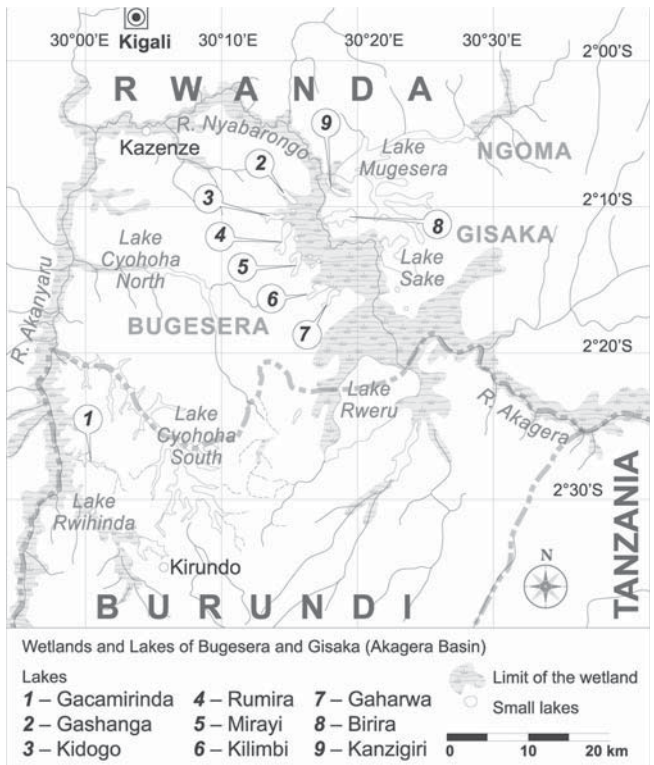


FIGURE 5.1 Sampling sites on Lake Cyohoha in November 2007 (Map from Ntakimazi, 1985)

The experimental fishing method involved using two (2) sets of multimesh gillnets made of 12 portions of 5 metres each, with successively 8, 10, 12, 15, 18.5, 22, 25, 30, 33, 38, 45 and 50mm mesh size (nod to nod). The total length of each set was 60m, the height being about 1.5m. This method allows capturing most of the fish biodiversity present in the site, as well as the relative importance of fish populations and therefore fish stocks available for fisheries.

Gillnets were set at daytime from 9 am to 4 pm, or at night time from 5 pm to 7 am. The captured fish was identified, counted and weighed.

Fisheries status and Fisheries management observations

Some fishing activity was observed in Akanyaru River and the associated wetlands but this was not on a regular basis, probably because the yields are not so good. Information on the fish biodiversity and abundance of species was collected through interviews with fishermen found at the river and wetlands and it indicated that most of the fishing activities in the sub-basin are conducted in the lake itself.

In Burundi, interviews were conducted at the landing sites to know the number of fishermen, the gears used, and the current catches in species and quantities. Information from the interviews indicated that most of the fishermen were not monitored and it was not not easy to get clear numbers of who are involved in the fishing activity. It seems any individual who needs to get fish simply goes to the lake with the gear within his reach. The total catches are not easy to assess because most of the fish caught is consumed within families.

In Rwanda, interviews with officials responsible for the fisheries cooperatives and the fisheries officers at the region, district and local level indicated that some data is available data on number of fishermen, gears and catches.

This was an indication that their is some professionalism in managing the fisheries resource on the Rwanda side. Records about landing sites, markets and consumers are kept.

5. 3. Results and discussion

5.3.1. Fish biodiversity and ecological needs of different species

5. 3.1.1. Fish species biodiversity

Table 5.2 shows the fish species recorded in the upper Akagera River system (above Rusumo Falls) including tributaries (Akanyaru and Nyabarongo rivers) and associated lakes. (Ntakimazi, 1985, Frank & al. 1984, this study).

TABLE 5.2: List of species reported in upper Akagera River system and Lake Cyohoha (Ntakimazi, 1985, Frank & al. 1984, this study).

(I): Introduced species; (**E)**: Endemic species to the sub-basin; **(X)**: Species present in Lake Cyohoha in 1991, but not seen (or reported) in 2007's sampling

	Family	**Species**	Upper Akagera river system	Lake Cyohoha
1	Cichlidae	*Astatoreochromis alluaudi* PELLEGRIN, 1903 **(I)**	x	X
2		*Haplochomis burtoni* (GUNTHER, 1894) **(I)**	x	X
3		*Haplochromis* Sp.	x	X
4		*Oreochromis leucosticus* (TREWAVAS, 1933) **(I)**	x	X
5		*Oreochromis macrochir* (BOULENGER, 1912. **(I)**	x	X
6		*Oreochromis niloticus* BOULENGER,1912 **(I)**	x	X
7		*Tilapia rendalli* (BOULENGER. 1896) **(I)**	x	X
8	Clariidae	*Clarias liocephalus* BOULENGER, 1898	x	X
9		*Clarias gariepinus* (BURCHELL, 1822) **(I)**	x	X
10	Cyprinidae	*Barbus acuticeps* MATTHES, 1959 **(E)**	x	(X)
11		*Barbus apleurogramma* BOULENGER, 1911	x	
12		*Barbus kerstenii* PETERS, 1868	x	X
13		*Barbus ruasae* PAPPENHEIM & BOULENGER, 1914	x	
14		*Cyprinus carpio* L. 1758 **(I)**	x	X
15		*Labeo victorianus* BOULENGER. 1901	x	

16	Lepidosirenidae	*Protopterus acthiopicus* HECKEL, 1851 **(I)**	x	X
17	Mastacembelidae	*Mastacembelus frenatus* BOULENGER, 1901	x	X
18	Mochocidae	*Synodontis ruandae* MATTHES, 1959 **(E)**	x	(X)
19	Mormyridae	*Pollimyrus nigricans* (BOULENGER, 1906)	x	
20	Poeciliidae	*Lacustricola pumilus* (BOULENGER, 1906)	x	
21	Schilbeidae	*Schilbe mystus* (L. 1762) **(I)**	x	
	Total		21	15

From the table, 21 fish species are reported in the upper Akagera sub-basin, of which 15 are known from Lake Cyohoha. In the lake, nine (9) species were introduced and two (2) shown in brackets are endemic to the sub-basin.

5. 3.1.2. Fish species of Lake Cyohoha Sub-Basin

CICHLID FISHES

Haplochromine species

These small cichlid species, very diversified in East African Great Lakes, are quite difficult to identify in the field and in the laboratory. In the 1980s, the trend in taxonomy was split which resulted in the huge genus *Haplochromis* being divided into many genera and sub genera (Greenwood, 1979), although the current trend is to come back to the former status (Van Oijen *et al.*, 1991).

In upper Akagera and Lake Cyohoha, four (4) forms of Haplochromine species can be distinguished:

One form has a yellow pattern mixed with black in lower parts. This group can be distinguished from the other Haplochromine species because it has five (5) anal pins and molar-shaped teeth. The species is *Astatoreochromis alluaudi* Pellegrin 1903 (**PHOTO** 5.5).

Small Haplochromine forms with a colour pattern globally blue mixed with yellow and red in lower parts, with dots on sub-rounded caudal fin were identified as *Haplochromis burtoni* (Günther, 1894) (**PHOTO** 5.6 and 5.8).

Haplochromine forms whose males are reddish with black on lower parts and brown caudal fin. Some of them are mature at very small size (7 to 8 cm), but larger forms (more that 15 cm) seem to be different. It could be a mix of two species yet to be identified. These were referred to as *Haplochromis sp1 & 2* (**PHOTO** 5.6 - upper photo - and Photo 5.7).

Astatoreochromis alluaudi, PELLEGRIN 1903, was introduced into Lake Mugesera (Rwanda) in 1962 with the purpose of controlling bilharzia but has spread to the other lakes of upper Akagera through Nyabarongo River. It is abundant in vegetation belts in the littoral zones of lakes.

It is generally known that this species is mostly a mollusc eater, but analysis of stomach contents of samples from Lake Rweru in 1982 revealed that the species was omnivorous with a trend to be detrivorous, probably because it did not find enough molluscs on the lake. This species seem to adapt its feeding regime to the most available food like plant detritus and insect. In Cyohoha, this species is restricted to the rare vegetation belts around the lake.

Haplochromis burtoni (Günther, 1894) is restricted to the shallow littoral zone, in contact with vegetation. The local name of the fish is itself "Inyamutete", meaning "those who live in floodplain plants".

This species was known from literature to inhabit the Lake Tanganyika system and it is not clear when it arrived in the upper Akagera system. It was observed in 1980s that is was a small omnivorous fish which is insectivorous and known to feed on lavae.
Haplochrormis Sp 1 & 2 (Photo 5.6 and 5.7) are native in Lake Cyohoha. They are also found in all zones of the lake (littoral and pelagic zone, bottom and surface). Their feeding regime seems to be the same as that one of *Haplochromis burtoni.*

Tilapiine species

Four species of the Tilapia group are found in Lake Cyohoha:
- *Oreochromis niloticus* BOULENGER, 1912
- *Oreochromis macrochir* (BOULENGER, 1912)
- *Oreochromis leucostictus* (TREWAVAS, 1933)
- *Tilapia rendalli* (BOULENGER, 1896)

PHOTO 5.1 : *Oreochromis niloticus*

Oreochromis niloticus was been introduced in Burundian and Rwandan waters several times since 1935 to 1950. The species is found in all the lake's zones but adults are mostly caught in semi littoral and pelagic zone, in upper layer of the water column. The fry and the juveniles live in the very shallow waters, out of reach of large predators and fishermen.

Oreochromis macrochir, native of Lake Mwero in south-east of DR Congo, was introduced in fish ponds in Burundi and Rwanda in 1940s and 1950s. It has since escaped to river and lakes system in upper Akagera sub-basin. This species lives in shallow littoral bay lakes.
In 1980s, the size range of individuals caught in Lake Cyohoha was between 10g and 780g (7 cm and 28 cm).

The two species of *Oreochromis* (above) feed mainly by a non selective filtration of suspended plankton, but they take some of their food on the bottom, including plant detritus. Juveniles (less than 3 cm) have a different feeding regime, as they feed mostly on zooplankton, on rotifers, and insects.

These two species are known to live in the same environment. They were introduced in the Akagera sub-basin with knowledge that they would occupy the same ecological niche. Hybridisation may occur between them, like in other tropical fishes (i.e. Madagascar), but as time goes one, one of the species becomes more adapted than the other. In 1980s, populations of *Oreochromis macrochir* and the hybrids *niloticus – macrochir* were already much fewer than those of *Oreochromis niloticus*. During this study, *O. macrochir* was not caught although fishermen sometimes catch them.

Tilapia rendalli (**PHOTO** 5.10) is also native of south-east DR Congo that was introduced in the upper Akagera basin in the 1960s.

In lakes, this species is found in the littoral zone close to vegetation belts, but can also be caught off shore. This species graze directly on living aquatic plants and plant detritus on the bottom, but in some periods of the year, it consumes large amounts of insects (chironomids) and zooplankton. The fishermen know that *Tilapia rendalli* is the only species of Tilapia in the region that can be caught with line fishing using insects as bait.

Oreochromis leucostictus (**PHOTO** 5.9) has been seen in Lake Cyohoha since only 2002. It was caught in lakes with a direct connection with Nyabarongo since the 1990s, like Lake Rweru. It is not known when this species native to Lake Albert region came to upper Akagera system. This detritivorous species generally restricted to littoral zones covered with vegetation is still quite rare in Cyohoha's fishing catch.

Cyprinid Fishes

Barbus acuticeps MATTHES, 1959

This large *Barbus* is endemic to upper Akagera system. Fishermen say that this species is common in Akanyaru and Nyabarongo rivers, and that it enters in the lake during flooding periods when Akanyaru waters connect with Cyohoha. This happens only in wet season, usually in April and May, when rainfall has been enough to induce floods and this is the likely reason it was not caught during this sampling.

Cyprinus carpio L. 1758

The common carp was introduced in Africa for aquaculture purpose. Its culture was tried in ponds in Rwanda by late 1970s and, from there, the species joined river Nyabarongo, Akanyaru and Akagera where it was reported in the 1980s. Since the 1990s it is caught in Lake Cyohoha in flooding periods. It is never abundant in the lake, probably because abiotic conditions and the predation pressure on juveniles prevent the species from being common.

Barbus kerstenii PETERS, 1868

According to fishermen, *Barbus kerstenii* PETERS, 1868, was once abundant in Lake Cyohoha and in the other lakes of the region, but in 1980s, it became very rare. The local name of the fish is "agahumbirajana", meaning "by hundreds of thousands". It was not been seen in 2007s sampling. This small *Barbus* might be disappearing from the lake.

It should be recalled that most of the *Barbus* species need to access river running waters for reproduction. Most of the small rivers and streams in the region have been modified for agriculture needs.

Clariid Fishes

Clarias liocephalus BOULENGER, 1898 (PHOTO 5.2)

In 1980s, *Clarias liocephalus* was a common species in the benthic zone of Lake Cyohoha. Lake population individuals had a size range between 15 and 35 cm total length (25 to 240 gr). The density of population is known to be higher in the middle of the lake during the dry seasons and much lower in the littoral zone in the peak of the rainy season. The densities are higher in the shallow waters and this correlats to the reproductive migration in flooding periods to the wetlands and tributaries.

The species feeds on small fish (Haplochromine species) as well as on benthic (chironomids and ordinates larva) and pelagic (chaoborids larva) invertebrates. Plant detritus and mineral particles are common in the gut as the fish feeds mostly on the bottom. Juveniles (3 to 11 cm) are more insectivorous and live in the floodplain and wetlandland around the lake. At adult size (15 cm and more), they enter into the lake, and include progressively small fish in their diet as they get larger.

In 2007 sampling, this species was caught in the lake, but the population was smaller, probably due to fishing pressure and the competition of introduced larger piscivorous species *Clarias gariepinus* and *Protopterus aethiopicus*.

PHOTO 5.2 : *Clarias liocephalus*

Clarias gariepinus (BURCHELL, 1822)

Clarias gariepinus (BURCHELL, 1822) is a common species in lower Akagera and in many other African hydrological systems. It was not known in upper Akagera system before late 1970s when it was introduced in fish ponds. From there, it escaped to Nyabarongo and Akanyaru and associated lakes in early 1980s. It has been caught in Lake Cyohoha since 1986. Since the 1990 and mostly in the 2000s, it was the main species caught in vegetated shallow places around Lake Cyohoha with the "Tilapias".

The feeding regime of *C. gariepinus* is quite known since it is widely raised in aquaculture. Most of all known food items have been found in *C. gariepinus* stomachs in natural conditions: insect larva and adults, plant grains and fruits, plant detritus, algae, zooplankton, eggs, ostracods, molluscs, and fish. This fish feeds on silted bottom as well as in open waters, but preferably in shallow vegetated waters, the main food taken being the most abundant in the biotope. Globally, it is admitted that the juveniles are omnivore with a trend to being insectivorous, the fish becoming piscivorous as it grows larger.

Like all clariids, *C. gariepinus* can survive in very poorly oxygenated waters thanks to its supra pharyngeal system. It is therefore not surprising that this species can live in all natural waters and artificial water systems in high altitude region, as reproduction is possible above 20°C. The species also needs vegetated floodplains for reproduction and juvenile's growth.

C. gariepinus was not caught in our 2007 gillnet sampling, but it was seen several times in fishermen's line fishing catches as shown in Photo 5.3.

PHOTO 5.3: Clarias gariepinus

MOCHOCID FISHES

Synodontis ruandae MATTHES, 1959

Synodontis ruandae MATTHES 1959 is an endemic species to upper Akagera. *Synodontis afrofischeri* HILGENDORF 1888 and *Synodontis victoriae* BOULENGER 1906 are its anatomic and ecological homologue respectively in lower Akagera and in Lake Victoria.

This fish has an extended feeding regime; all kinds of food items were found in the stomach contents, but invertebrates and mostly chironomid larva are dominant among its preys. Molluscs, plant detritus and copepods also form part of its diet. It is therefore an omnivorous species with a trend to being insectivorous, which feeds on the bottom as well as in surface waters.

In 1980s and 1990s, the species was caught in all zones of Lake Cyohoha, but mostly in pelagic zones, in deep water as well as in surface layers. It was noted that catches were very irregular – from nil to hundreds of individuals – suggesting that these fish are schooling in the lake.

The other fact was that only very large individuals were caught in Lake Cyohoha unlike in Lake Rweru where all sizes were seen. It is thought that it is a migratory species, moving to rivers like Akanyaru, Nyabarongo and Akagera for reproduction, and coming back in the lake with juveniles for the growth. When this migration is not possible, there might be no breeding. If the flooding which connect Akanyaru River to the lake does not occur, especially in years with low rainfall, the breeding during the period without flooding might be interrupted. As a result, their population may not be renewed.

Since 2002, *Synodontis ruandae* has not been seen in Lake Cyohoha but it still reported in Akanyaru and Nyabarongo rivers. The main cause of this is probably the deficit rainfall observed in the region since 1999 which did not allow the seasonal connection between the lake and Akanyaru River, through the increase of fishing pressure with small mesh size nets might have accelerated the process.

Mastacembelid Fishes

Mastacembelus frenatus **BOULENGER, 1901**

This river spiny eel is found in the lake's littoral zone close to lateral floodplains and river mouths. It feeds exclusively at night time on ephemeroptera and chironomid larva.

Quite common in gillnet catches from vegetated areas in Lake Cyohoha in the 1980s, but was not caught in 2007 sampling. It is still reported in the lake by fishermen, but has become very rare.

Lungfish

Protopterus aethiopicus **HECKEL, 1851**

The lungfish (Photo 5.4) was first caught in upper Akagera in the 2000s after having been introduced in Lake Muhazi. Its spread in upper Akagera system and associated lakes which is an indication that there is an available ecological niche for it, notably food and appropriate biotope for reproduction.

This voracious species feeds mostly on the abundant populations of Haplochromine species and other small fishes and invertebrates found in the lake.

Protopterus aethiopicus also needs vegetated floodplains around the lake for reproduction and juvenile growth.

It was mostly observed in the fishermen catches at the northern wetland connecting the lake to River Akanyaru.

PHOTO **5.4**: *Protopterus aethiopicus*

5.3.1.3 The status of fish species in Lake Cyohoha

Lake Cyohoha is inhabited by 15 species of fish species of which: two (2) are endemic to upper Akagera system (*Barbus acuticeps, Synodontis ruandae);* six are native to the Sub-Basin (*Barbus kerstenii, Barbus acuticeps, Haplochromis Sp1 & 2, Synodontis ruandae, Clarias liocephalus, Mastacembelus frenatus*); nine (9) were recently introduced in the sub-basin (*Astatoreochromis alluaudi, Haplochomis burtoni, Oreochromis leucosticus, Oreochromis macrochir, Oreochromis niloticus, Tilapia rendalli, Clarias gariepinus, Cyprinus carpio, Protopterus aethiopicus*); two (2) species are probably threatened with extinction (*Oreochromis macrochir*, *Barbus kerstenii*); and one (1) is currently not seen in the lake although it is in the neighbouring Akanyaru River (*Synodontis ruandae*). Three (3) introduced species are of economic importance (*Oreochromis niloticus, Clarias gariepinus, Protopterus aethiopicus).*

Most of the species in the sub-basin are river types, meaning that they need running water or floodplains for reproduction and juvenile growth. These lateral ecosystems need to be protected in order to keep the lake productive.

The native fish fauna is depauperated and the lake ecosystem was observed to have a lot of phytoplankton (the water is green). The Haplochromine populations are hervested like other types of fishes.

5.3.1.4. Fish stocks available for fisheries

The relative distribution of different fish species in Lake Cyohoha can be derived from catches of the experimental sampling as they show catches of all the species and all sizes.

TABLE 5.3, and **FIGURE** 5.2, smaller species of Haplochromines are represented by large populations. This shows the potential to be harvested and overall contribution to the food web of the ecosystem.

The biomass of planktivorous species (Tilapias) is low. After the sampling session with experimental gillnet sets, very few Tilapia with an individual weight above 100g have were seen. In TABLE 5.3 shows that few Tilapia (*Oreochromis niloticus*, *Tilapias rendalli*) were caught in gillnets. This is presumably a consequence of a high fishing pressure.

Data on fishing effort shows that there is a reduction in the catches. In Burundian waters of the lake, production was about 280 tons per year in the period between 1966 and 1968 (47kg /ha / year) (Roest, 1977). In 1981 - 1982, the annual production was evaluated at 75 tons (12kg/ ha / year) (Ntakimazi, 1985). In Rwandan waters, production for the same period was estimated at 17kg/ha/year with a fishing effort three (3) times higher (Chevalier, 1981).

It will be interesting to record the contribution of the introduced fish species in the lake (*Clarias* and *Protopterus*) to asses their potential yield.

PHOTO 5.5: *Astatoreochromis alluaudii*

PHOTO 5.6: *Haplochromis sp* 1 (up)
Haplochromis burtoni (down)

PHOTOS 5.7 and 5.8: *Haplochromis sp 2* (up)
Haplochromis burtoni (down)

Date	26-Nov		27-Nov		28-Nov		28-Nov		29-Nov		29-Nov		30-Nov					
Location and time	Iyalanda littoral night time		Iyalanda bay day time		Iyalanda pelagic night time		Kiri littoral day time		Kiri pelagic night time		Kigina littoral day time		Kigina pelagic night time		Totals		Mean weight	Max weight
Species	Nb	Wt	Nb	Wt	Nb	Wt	Nb	Wt	Nb	Wt	Nb	Wt	Nb	Wt	Nb	Wt		
Haplochromis sp	44	330	270	1485	94	231	2	5	229	1243	10	58	234	845	**883**	**4197**	5	
Haplochromis burtoni	24	170			22	96	103	270	161	458	106	508	296	1203	**712**	**2705**	4	
Oreochromis niloticus	3	76	16	356	4	118	2	68	4	85			7	225	**36**	**928**	26	130
Tilapia rendalli	4	135	2	240									7	131	**13**	**506**	39	66
Clarias liocephalus	4	85			1	25			1	36			2	48	**8**	**194**	24	
Astatoreochromis alluaudi	2	10	20	100			2	5	5	25	12	182	2	50	**43**	**372**	9	
Oreochromis leucostictus			4	40					1	33	1	28			**6**	**101**	17	

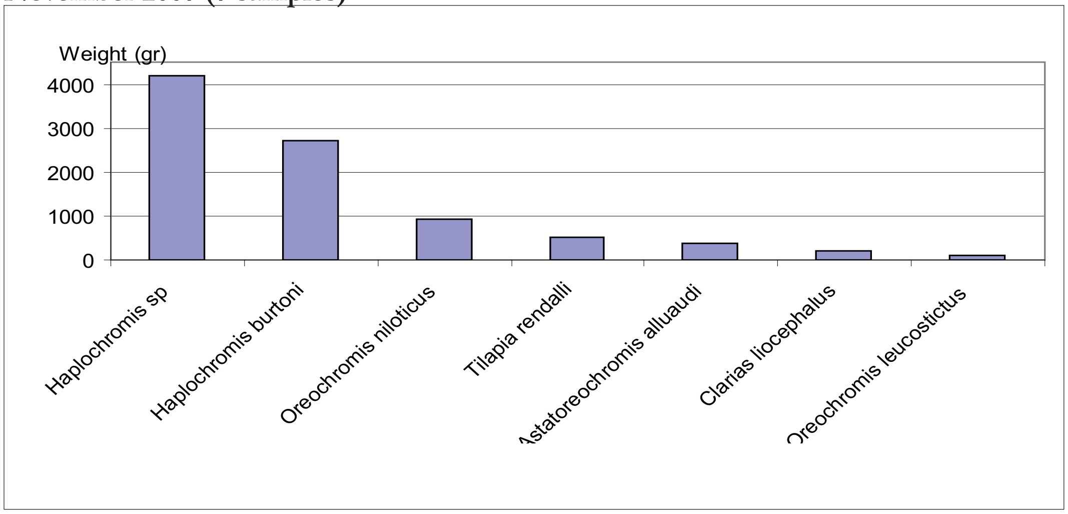
TABLE 5.3: Synthesis of catches of fishes with the experimental multi mesh gillnets at the sampling sites

Nb = numbers; Wt = Total weight in Lake Cyohoha in November 2007

PHOTO 5.9: *Oreochromis leucostictus*

PHOTO 5.10: *Tilapia rendalli*

FIGURE 5.2: Total weight of fish caught in experimental fishing in Lake Cyohoha in November 2007 (7 samples)



5.4. Fisheries management in Lake Cyohoha

Although surrounding populations in the two countries meet regularly in their different activities (visits, trade, fishing), the fisheries management on Lake Cyohoha is quite different in Rwanda and in Burundi.

In Rwanda

Fishing regulations on Lake Cyohoha, like with other lakes in the Akagera Basin, are based on a local co-management system, under the control of state services. Fishermen are organised in one or more local formal associations (cooperatives), working from one or more landing sites. Isolated individuals are not allowed to access the lake for fishing activities.

The cooperative society, IGISUBIZO, is in charge of fisheries in Rwanda's part of Lake Cyohoha. Created formally in February 2007, it is operating from three (3) landing sites: the main one is Ngeruka (in the Rutonde sector), and the two others are Ruhuha in the north and Kamabuye in the south. The cooperative as at the beginninig of 2008 had 78 members, and about 35 of them are active fishermen. Its activities are supervised by a local fisheries officer from the Ministry of Agriculture and Animal Resources, who reports to senior officers at district and regional levels.

The cooperative is also in charge of protecting the resource. It organises patrols regularly on the lake, to discourage the "poachers" (non members of the association) and fishermen using prohibited gears. Fishing is prohibited along the shoreline and in reproduction grounds which are generally at the tip of the lake's branches.

Likewise, fishing with mesh size nets of less than 4 inches is normally prohibited, as well as beating water to frighten the fish. The "poachers" are reported to fisheries officers and local police for a fine, confiscation of nets, and even prison.

The fisheries cooperative on Lake Cyohoha owns 17 fishing units each using 20 gillnets (a stretched net is about 100m long, but is 30m when mounted). Eighteen (18) supplementary units are working with their own nets. Some of the fishermen use long-lines to target specifically Clarias and Protopterus.

After landing, the fishermen using the cooperative's nets are given 10 fish (about 2.5kg) from their catch, for their family consumption. Those using their materials sell the catch to the cooperative at 350 FR/kg for Tilapias (250 FR for *Clarias* and *Protopterus*), of which they leave 50 FR/kg to the association's cashier.

The predominantly caught species are *Oreochromis niloticus* (Tilapia), *Clarias gariepinus* (Inkube) and *Protopterus aethiopicus* (Imamba).

The cooperative records show a decrease in catches of Tilapia since 2006. The monthly Tilapias catch is about 20 to 30kg, less than that of *Clarias* (about 250kg/month) and *Protopterus* (about 50kg/month) which were introduced in the lake. (These figures are of fish "sold" by the cooperative and exclude that "eaten" by the fishermen).

In November 2007 their was indication by the regional fisheries officers that catches in Lake Cyohoha were 152kg for Tilapias, 188kg for *Clarias* and 19kg for *Protopterus*, with a total of 359kg. If this is correct, and there are 35 active fishermen, it implies that each of them would have go with about 10kg of fish in 20 days (0.5 kg/day). This suggests a need for quality assurance in data collection.

The fisheries officers suspect that the whole catch is not declared to avoid paying more tax. This could be the reason the cooperatives are now asked to pay a fixed amount. The cooperative on Lake Cyohoha pays a tax of 83,500 FR per month, plus a local tax of 200 FR per month for each boat. The cooperative officials however think these taxes are too high and say they are likely to stop fishing as their activity is not productive.

The main problem is that their fellow fishermen in Burundi are fishing indiscrimnately by using all the fishing techniques prohibited in Rwanda: small mesh size nets and even mosquito nets, beach seines, and fish frightening techniques. Harmonisation of fishing regulations and cooperation between the two countries could therefore go a long way in addressing some of these issues.

In Burundi

The fishing activities in Burundi by 2008 were inadequately supervised to the extent that any individual who needed fish for personal consumption or to sell could access the lake. Their limitation was lack of fishing gears.

Until the 1990s, fisheries regulations prohibited use of gillnets with mesh size of less than 4 inches. But the local administrative structures inadequately enforced these regulations. After 1999, the situation became more serious but was coupled with the severe drought experienced in the region leading to crop loss, food shortage, famines, and a big drop in the lake's level. So a higher number of people moved into the lake to fish for to survive. Since the gears were rare, mosquito nets were used, which contributed to overexploitation of the resources and a dramatic drop in fish catches.

The management of the fisheries resource is not professional because every body including farmers and children are involved.

To solve this situation, partners like FAO and World Bank have encouraged setting up of fishermen associations which have been given gillnets and seines with regular mesh size (4 inches) as indicated in TABLE 5.4 to replace mosquito nets and other prohibited gears.

TABLE 5.4: Number of gillnets provided by FAO to fishermen around Lake Cyohoha in 2006

Commune	Localities	Number of nets
Bugabira	Kiri	16
	Gitwe, Ngugo	59
	Nyamabuye	141
Kirundo	Iyalanda	129
	Kigozi	19
	Ceru, Rukuramigabo	125
Busoni	Kibonde, Muramba	165
	Total number of nets	654

The World Bank provided two (2) fishing nets and four (4) boats at Iyalanda and one (1) net at Gaturanda in Bugabira.

In 2006, statistics were collected by the officer in charge of fisheries in the Department of Agriculture at provincial level (Kirundo). The figures are indicated in TABLE 5.5.

TABLE 5.5: Fisheries statistics in the Burundian side of Lake Cyohoha in 2006

Commune	Landing beaches	Number of associations	Fish catches (kg)
Bugabira	8	19	2440
Busoni	3	3	650
Kirundo	5	6	1650
Total	16	28	4740

Most of those associations are informal and have just been set up to obtain nets and other materials from fund providers. Each association has, in most cases, more than one hundred members. It can, therefore, be understood that the income, calculated by member, is far from encouraging.

In 2007, certain landing sites were officially recognised by the administration and are indicated in TABLE 5.6; even though some fishermen try to create others in order to keep landing close to their home.

TABLE 5.6: Recognised fisheries landing beaches on Lake Cyohoha in Burundi (2007)

Commune	Landing beaches
Bugabira	Kiri
	Nyamabuye
	Kigina (+ Gaturanda)
	Kiyonza
Kirundo	Iyalanda
	Kigozi
	Ceru
Busoni	Kibonde (Murambi)
	Marembo

All the fishermen met during the study complained that 4 inch size gillnets are not able to catch much fish in Lake Cyohoha; that is why they have abandoned them. It is said that these nets are kept at home and some of the fishermen have gone to use them on Lake Rweru where they can still get some good catch. Many nets were are even sold there.

The fishermen on Lake Cyohoha continued with their very small mesh size nets (2 inches, hidden mosquito nets - Photos 5.11 to 5.13), and line fishing, the latter giving better results in wetland areas. Their catches are consumed by families and sold in local markets. Fisheries statistics were not collected on Lake Cyohoha in 2007.

All fishermen recall the high catches in 1996 when the fishing resumed after a two-year closure (1994 and 1995) due to civil war in Rwanda and Burundi. After three (3) years of heavy fishing, the catches dropped again.

Generally, fish resources on the Burundi side of Lake Cyohoha suffer over-exploitation due to lack of administrative management by way of enforcing regulations on fishing gear and net mesh size, but also on the number of fishermen who could reasonably exploit the resource in a sustainable way. There are so many people whose fish demand can never be met by the lake.

PHOTO 5.11: Catches of Tilapia (*O. niloticus*) in Lake Cyohoha (Burundi)

PHOTO 5.12 & 5.13: Mosquito net in Burundi and its catches (drying juvenile fish)

5.5. Proposal for authorised nets mesh size for fisheries in Lake Cyohoha

It is known that a responsible fisheries management allows catching only mature fish; that is individual fish that has reproduced at least once.

As fishing in Lake Cyohoha targets mostly Tilapia, we indicate in FIGURE 5.3, the size at first maturity for this species was calculated (in this study) from primary data collected in experimental fishing conducted in Lake Cyohoha in 1981-1982 (Ntakimazi, 1985).

Gonad maturity status is identified as follows (simplified from Gwahaba, 1976):

1. Very small sexual organs close under the vertebral column. Testes and ovaries are transparent, colourless to grey.
2. Testes and ovaries translucent; length half the length of ventral capacity.
3. Testes and ovaries opaque, reddish with blood capillaries; occupy a half to two-third of ventral cavity. Eggs clearly visible to the eye as whitish granular
4. Sexual organs filling ventral cavity. Testes white drops of milt fall under pressure. Eggs completely round, some already ripe.

The vertical line in FIGURE 5.3 indicates the smallest total length at which an individual had gonads at maturity status 4. This means that the smallest reproducing females and males of *Oreochromis niloticus* had a total length of, respectively, 15cm and 17cm. The size at first maturity today is probably in the same range.

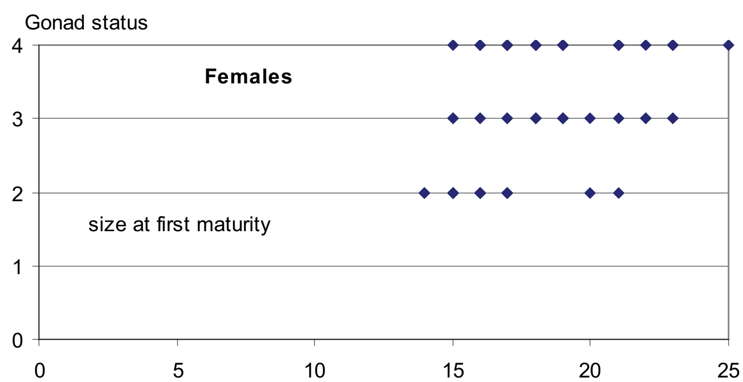


FIGURE 5.3: Size of the smallest reproducing *Oreochromis niloticus* in Lake Cyohoha (analysis of primary data collected in 1981 -1982)

If we refer to the length-weight relationship established for the same species (FIGURE 5.4), fish of these sizes have an individual weight between 79g and 107g.

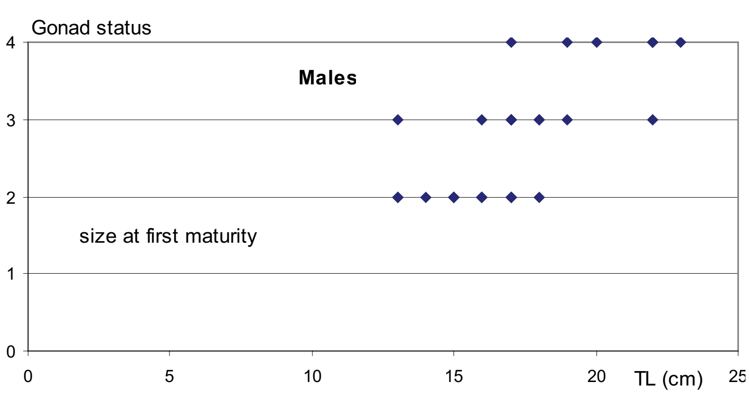


FIGURE 5.4: Length - Weight relationship in Oreochromis niloticus in Lake Cyohoha (analysis of primary data collected in 1981 -1982)

These sizes at first reproduction are smaller than those observed in other Eastern Africa lakes, for example, 19cm in Lake Ihema and 20cm in Lake Edward (Plisnier, 1984; Mukankomeje, 1984; Gwahaba, 1973). It is likely that Tilapia populations in Lake Cyohoha have been exposed for several years to a negative selection pressure by small mesh size nets, which eliminated individuals with a better growth potential but reproducing late for the first time.

To reverse this trend, Tilapias to be harvested should be individuals with a total length above 18cm, or with a weight above 100g.

The range of individual weight of Nile tilapia (*Oreochromis niloticus*) caught in different net mesh size used in experimental fisheries in Lake Cyohoha in 1981-1982 (10 , 15, 20, 25, 31, 40, 50, 60mm nod to nod) is indicated in **FIGURE** 5.5.

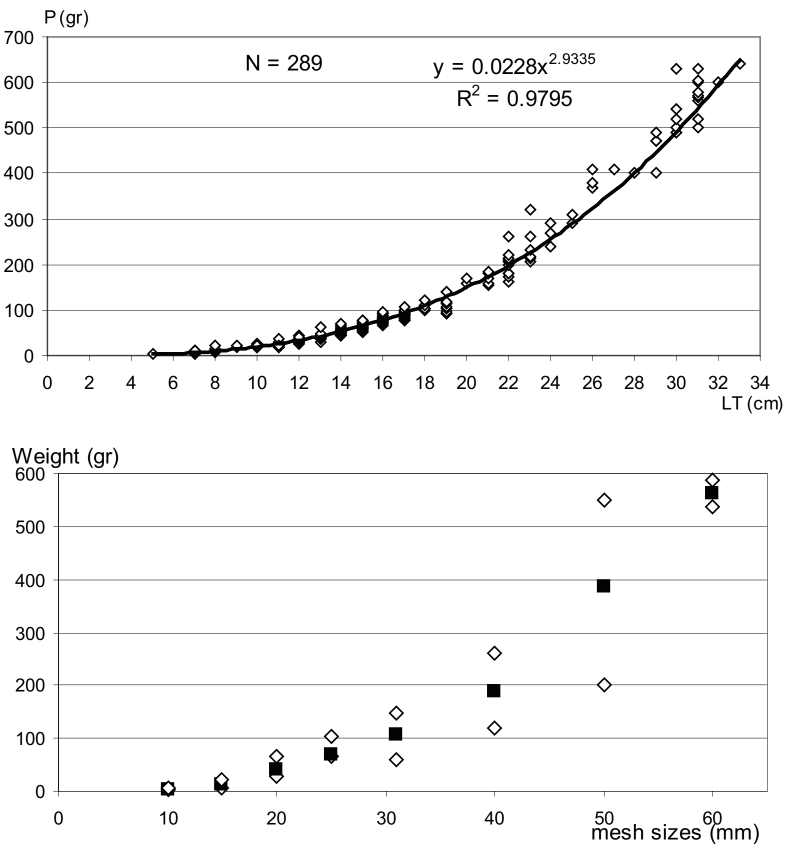


FIGURE 5.5: Mean and range of individual weights of Nile tilapia (*Oreochromis niloticus*) caught in different net mesh size in Lakes Cyohoha and Rweru in 1981-1982

It appears that only net mesh size of 40mm nod to nod and above, allows catching fish of at least 100g. The conversion table (**TABLE** 5.7) between mesh sizes in millimetres nod to nod and stretched mesh in inches indicates that 3.5 inch is the best corresponding size.

TABLE 5.7: Conversion table between stretched mesh in inches and mesh nod to nod in millimetres

Stretched mesh in inches	Mesh nod to nod in millimetres
1	13

1.5	19
2	25
2.5	32
3	38
3.5 (*)	**44**
4	51
4.5	57
5	64

(*): Recommended mesh size

5.6. Conclusions

Literature review, on-field sampling and interviews were conducted in November 2007 in Lake Cyohoha Sub-Basin to assess the current fish fauna biodiversity, as well as fisheries status and fisheries management in the two countries sharing the lake.

It was found that fish biodiversity in the sub-basin includes 21 species; Lake Cyohoha itself being inhabited by 15 or 16 species of fish, of which:

- two (2) are endemic to upper Akagera system,
- six (6) are native to the sub-basin,
- nine (9) were introduced in the sub-basin, some of them recently,
- two (2) species are probably going extinct in the lake,
- one (1) is currently not seen in the lake although still in the neighbouring Akanyaru River;
- three (3) are of economic importance in fisheries.

Most of these species are river type, as they need running water or shallow floodplains for reproduction and juvenile growth.

The fish stocks available for fisheries have decreased as a consequence of fisheries pressure, but in-depth studies are needed to assess the actual catches in the two sides (Rwandan and Burundian) of Lake Cyohoha.

Fisheries regulations on the Rwandan side of the lake are based on a local co-management system, under the control of state services. The fisheries pressure that could allow sustainable yields is yet to be established and catches statistics collection are to be improved to get reliable statistics.

On the Burundian part of the lake, fish resources suffer from over-exploitation, due to the weakness of regulations enforcement structures; mostly those to do with fishing gears and fishing methods control.

After an analysis of the size of Tilapia at their first reproduction, it was noted that, although some individuals mature at 70g (15cm total length), most have reproduced at about 100g (after 17 cm total length). An analysis of fish caught in different net mesh sizes showed these individuals of 100g and more can be harvested with 3.5 inch nets and above.

Recommendations

The fish biodiversity of Lake Cyohoha is of great importance to people's livelihood in Burundi and Rwanda. It has been observed during this study that there is over-exploitation of the fisheries resource to the extent that it is not sustainable. Urgent action is needed to protect the habitat and to reduce the fishing pressure. Among the recommendations arising from the studies, the following are major:

- The wetland around Lake Cyohoha and mostly the strip connecting it to Akanyaru River must be well conserved in order to secures breeding grounds for the fish.
- Urgent action needs to be taken to stop the over-exploitation.
- Restocking Lake Cyohoha with *Oreochromis niloticus* should be considered to improve the catches.
- The lake should be closed to no-fishing seasons to allow fish populations to recover.
- Cooperation and collaboration between Burundi and Rwanda for a responsible management of Lake Cyohoha resources is urgently need.

From the results of this study on fish fauna and fisheries on Lake Cyohoha Sub-Basin, it appears the above ecosystem is of great interest for the biodiversity in the upper Akagera system. The lake, the rivers and the wetland function as an ecosystem.

5.7. Main issues and related recommendations

From this study, important issues have been highlighted about fish biodiversity and ecology and the need for fisheries management.

Fisheries biodiversity and ecological needs

Lake Cyohoha, like other lakes in upper Akagera system had a relatively poor native fish biodiversity. Introduction of species did not improve the situation. It would not be wise to try to introduce other species without prior in-depth studies on the various lake zones and ecological niches.

Some species are becoming rare, probably because of human induced ecosystem changes in and around the lake and to fisheries pressure. This needs to be addressed.

Most of the fish species are river type which implies that they need to access vegetated littoral shallow waters, floodplains and river running waters to reproduce and for juvenile growth. Wetlands around the lake and most of its hydrological connections to Akanyaru River must be conserved in order to mainatin the ecosystem's integrity.

Fisheries status and management

There is need for the potential fish yields of the lake to be assesed. This information is needed by all the stakeholders to know the number of people and fishing gears that could be allowed to exploit the resource in a sustainable way, the investment needed in the fisheries business, and the income (and taxes) to be expected.

The fisheries stocks of the lake have been (and are still being) over-exploited with drops in catches. There is urgent need to stop the overexploitation.

The demand for fish around Lake Cyohoha is much higher than the lake's production. While a policy on the sharing of this limited resources needs to be urgently constructed, the long term solution lies in the development of alternative sources of food and income.

To improve the potential of Tilapia catches in the lake, restocking with *Oreochromis niloticus* can be a viable option, in addition to establishing fishing zones on the lake.

In Burundi, a management structure with the authority to enforce fishing regulations is urgently needed to monitor and control the fishing effort (number of fishermen and gears, fishing techniques, etc.), to reverse the current collapse of the catches.

From this study, nets of 3.5 inch (and above) mesh size should be allowed on the lake to target Tilapias.

Cooperation and collaboration between Burundi and Rwanda for a responsible management of Lake's Cyohoha resources is more than a necessity; the initiative should come from the highest level of the states, and spread down to the local people. This could be realised through a joint management committee.

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