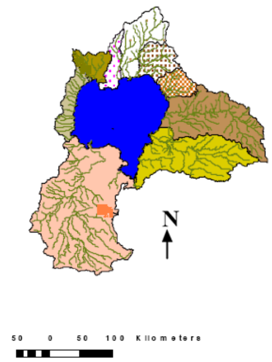


THE BIODIVERSITY, WETLANDS AND WATER QUALITY OF THE LAKE TANA SUB BASIN (LTSB).

2009

THE BIODIVERSITY, WETLANDS AND WATER QUALITY OF THE LAKE TANA SUB BASIN (LTSB).

Contributing Authors

Seyoum Mengistou
Zerhin Woldu, Emiru Seyoum,
Eshete Dejen, Samy A Saber, Wambura John,
Bakuneta Chris, Bezarhir Emana

Edited by

Henry Busulwa and Christine Lippai

Nile Transboundary Environmental Action Project
NILE BASIN INITIATIVE

This study was made possible with the financial support from the Canadian International Development Agency and The Netherlands government provided through the Nile Basin Trust Fund managed by the World Bank. NTEAP would like to take this opportunity to thank all development partners for their continued support.

Published by: The Nile Basin Initiative – Nile Transboundary Environmental Action Project

Citation: Chapter Author (2009). ***Chapter Title. In:*** Henry Busulwa and Christine Lippai(Eds). **The Wetlands, Biodiversity and Water quality Status of Lake Tana Sub Basin**. *Wetlands and Biodiversity Conservation Component of the Nile Transboundary Environmental Action Project.* Nile Basin Initiative Secretariat. pp

Professional Editing: Christine Lippai

Printed By:

Available from: Nile Basin Initiative Secretariat
P. O. Box 192,
Entebbe Uganda.
Tel +256 414 321329/321424
www.nilebasin.org

ISBN: 978 9970 148 27 1

Acknowledgement

The Nile Transboundary Environmental Action Project is very grateful to the experts who carried who carried the studies presented in this report, the stakeholders from Ethiopia who participated in discussing the results and the reviewers who guided the technical inputs into the studies.

Special gratitude goes to the Regional Wetlands and Biodiversity Working group members of the Nile Basin region who made constructive inputs by guiding the studies to completion and were directly involved in reviewing the draft reports

Thanks also go to the Development Partners of the Nilebasin Initiative whose support made the studies possible.

The Nile Transboundary Environmental Action Project.

Foreword

The Nile Basin Initiative (NBI) is a partnership between riparian countries of the Nile: the Republic of Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, the Republic of The Sudan, the United Republic of Tanzania, and Uganda. The NBI's shared vision is to "achieve sustainable socioeconomic development through the equitable utilization of and benefit from the common Nile Basin water resources". To translate this shared vision into action, there are two complementary programs: the Shared Vision Program (SVP), which creates a basin wide enabling environment for sustainable development; and the Subsidiary Action Programs (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 eight Projects under the NBI's Shared Vision Program, was 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 piloted by the Wetlands and Biodiversity Conservation component of NTEAP, to demonstrate the understanding of the functions of wetlands, biodiversity and water resources in sustainable development. The component's approach used regionally and nationally focused initiatives within the Nile basin countries.

Through extensive consultations, the component prioritized the selection of the sites without losing touch with the knowledge and experiences of existing networks. This approach provided trans-boundary and basin-wide perspectives in generating information that complements national and regional efforts in wetlands and natural resources conservation management programs.

This study was a response to requests by the Eastern Nile Subsidiary Action Plan (ENSAP), which envisaged a series of investment and development projects in the Lake Tana sub-basin as a matter of priority. The selection of Lake Tana sub-basin 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 Lake Tana sub-basin, its wetlands, catchments and forests are very important sources of natural resources and habitats for a variety of fauna especially birds and flora. It is also evident that the livelihoods of the communities living around the sub-basin depend on various services and resources. An in-depth integrated analysis of the biodiversity, wetlands and limnology of Lake Tana and its sub-basin would not only serve as a baseline but also guide any investment programs. The study, therefore, covered the fields of limnology, botany, ichthyology, herpetology, mammalogy, ornithology, entomology and socio-economy.

The objective of the study was to assess the wetlands and biodiversity in the Lake Tana sub-basin with view to harmonize the socio-economic development and sustainable conservation of its natural resources. Studies on limnology and water quality were carried out to complement the wetlands and biodiversity surveys in order to obtain ecosystem-wide solutions to the major threats facing the lake and its associated wetlands. These threats include rapid population growth and agricultural activities in the basin, unwise land use practices, intense erosion and silt loading in river and lake basins, severe organic nutrient pollution, wetland drainage and unsustainable water usage. The inadequate institutional and legislative deterrents to regulate unsustainable practices are a serious problem in the sub-basin and a major handicap when it comes to trans-boundary water resources management in the Blue-Nile and the Nile basins.

This report is the first detailed attempt to address the above threats in an integrated and eco-systematic manner. The water quality, in addition to the ecological and economic condition of the sub-basin has been appraised, highlighting the roles of wetlands and biodiversity in supporting sustainable development. The biophysical environment of the Lake Tana sub-basin and its catchment has been described in terms of its climate, geology, topography, and structure and soil erosion, with a brief explanation of the hydrological regime of the Lake Tana catchment. The studies explored the ecological processes and the impact of wetland modifications and habitat and biodiversity loss, on water quality and biodiversity. For instance, it is now known that Lake Tana acts as a silt refinery for the 5,000 tonnes of sediment received from four major influent rivers. This has drastically affected the lake limnology with regard to its high turbidity, high rates of retention of nutrients and organic matter and low water retention time (WRT), which have all had an effect on the lake's biodiversity. An assessment of the economic value and major threats, together with the underlying socio-economic functions was carried out to assist with future effective management of the sub-basin resources.

Wetlands are the remnant hot-spots of biodiversity, such as the mosaic deltaic floodplains and river banks, and their presence has continued to provide a buffer to the choking sediments. *Oriza longistaminata* is a wild rice species that only occurs in Africa and is found in the wetlands of Lake Tana. 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. The wetlands of Lake Tana should be protected as nature reserves.

People also harvest the forest for construction and making farm implements. The monasteries (holy places) that exist in the region have contributed to conservation in the area and resulted in continued existence of remnant natural forests with afromontane vegetation.

However, most tree species in the landscapes which are useful for various purposes have been over-harvested and only a few species of *Ficus, Acacia, Croton macrostachyus* and *Cordia africana* can be observed breaking the uniformity of the landscape around homesteads and in fields. Guidelines to sustainable livelihoods need to be devised for the people living in the highly-populated Lake Tana sub-basin. The churches in the area are institutions that could serve as the sentinel of biodiversity conservation: through their widespread public influence, churches can mobilize the local communities for wise use of the wetlands and the sub-basin's resources. The local people need to be sensitized and guided to reduce the loss of the semi-natural wetland habitat to agriculture and reverse the degradation that has occurred in recent years.

Because of the relatively improved availability of water, the area has become the subject of recent focus on agricultural and hydropower development. The hydropower development along the old course of the Nile River and the new inter-drainage change along the Beles River has necessitated a regulation in the lake level. The regulation of the river flow along the Nile course is a potential threat to the riparian forest as it deprives the species of the seasonal fluctuation of the moisture regime on which their establishment and survival depends.

It is important to learn that some species such as *Mimusops kummel* and *Diospyros mespiliformis* produce edible fruits on which many people base their income. Some people in Zeghe Peninsula and the islands live on the forest coffee which they manage and harvest traditionally. However, felling the trees for local consumption or for sale in Bahir Dar and other towns is threatening the sustainability of the forests.

The loss of wetlands to farming and the regression of papyrus beds are ongoing problems in the area. There is a visible loss of habitat for fish, amphibians, birds, invetebrates and mammals. Amphibians in many ways help protect humans from dangerous diseases, for example in mosquito control. It is also important to conserve the unique species-flock of *Labeobarbus* fish, together with the maintenance of external and internal energy sources (nutrients, detritus) and consumers, including birds and mammals whose habitats are also threatened. Although development projects in the Lake Tana sub-basin (dams, irrigation schemes, tourist hotels, other infrastructures, and industries) prepare Environmental Impact Assessment (EIA) studies, this study can provide additional reference to the impacts that may not have been addressed by the EIA.

It is strongly recommended that the lake and its wetlands should be given the special protection status of a Ramsar site. This would provide a necessary step to achieving international recognition and support for further activities. The Lake Tana and its catchment are a potential eco-tourism corridor. The wise use concept and IWRM watershed management will enable conservation and stabilization of the soil and reduce the silt load to the lake.

The eventual recovery of the vegetation of watersheds would pave the way for the return of the species which have been lost. It is therefore imperative to establish the recommended Lake Tana Basin Authority (LTBA) that will bring all development efforts in the sub-basin under one umbrella. The coordination authority will guide the development initiatives in Lake Tana and its wetlands and caution to mitigate the imbalances caused by exacerbated impacts, such as higher sediment loading, nutrient retention and the rapid expansion of the macrophytes in the littoral zone of the lake.

This integrated study, the first of its kind in the sub-basin, is in line with the Agriculture Led Development and Environmental Protection Policies of Ethiopia and the Nile Basin Initiative. The possible investment opportunities that are included as recommendations in various chapters of this book, should benefit from an improved legislation that includes developing national wetlands and biodiversity policies so that sound planning measures are developed for the conservation of the overall environment and ecological processes while sustaining agricultural production. This will fill the regulatory gap and provide a basis for institutional mandates for management of Lake Tana sub-basin wetlands and biodiversity and prevent habitat losses in an integrated eco-systematic approach. For example water dam constructions for agricultural production can also cater for the needs (feeding, roosting, breeding and refuge) of both migratory and non-migratory bird species. An attempt has been made to propose major areas of investment in the various chapters of this study. This book is a contribution towards further consolidated research and development endeavors. Continued appropriate data collection will fill the gaps identified to monitor and strengthen appropriate management measures for the wetlands and biodiversity.

Gedion Asfaw
Regional Project Manager
Nile Transboundary Environment Action Project

THE LAKE TANA SUB-BASIN

Henry Busulwa
Wetlands Lead Specialist, NTEAP
PO Box 2891 Khartoum

1. Introduction

The Lake Tana Sub-Basin (LTSB) is geographically located between latitude 10°57'–12°47'N and longitude 36°38'- 38°14'E, in the Amhara Regional State in the highlands of northern Federal Democratic Republic of Ethiopia. The LTSB is estimated to have a total area of 16,500 km^2. Its landscape is part of the western plateau of Ethiopia and includes features such as the escarpments of Gonder and Gojam, the lower plains surrounding the lake that forms extensive wetlands during the rainy season (ie Dembiya, Fogera and Kunzila plains in the north, east and southwest respectively) and the capital city of Amhara Region, Bahir Dar, situated on the southern shore by the exit of the Abay river. The lake and its catchment supports a riparian human population of up to 2.5 million who derive their livelihoods from the resources of the lake, wetlands and forests which offer water resources for irrigation and production of hydro-electricity, and also offer energy fuels for city, towns and kebeles[1]. The area around the lake has been cultivated for centuries contributing directly and indirectly to livelihoods. In addition, it is estimated that the sub-basin significantly contributes to the livelihoods of tens of millions of people in the lower Nile River basin. The fish resource potential of Lake Tana itself is over 10,000 metric tonnes per year (Wudneh, 1998), but the current catch is only 3,000 tonnes (FPME, 2007). Agriculture, predominantly rain-fed, is the main occupation of the Lake Tana sub-basin economy. The surrounding flood plains known as Fogera, Dembiya, Alefa and Achefer, have been intensively cultivated areas for centuries (**Getahun, *et al* 2008)**.

1.1 Lake Tana

Lake Tana is located at latitude 12°00'N, and longitude 37°15'E on the basaltic Plateau of the North Western highlands of Ethiopia. Its surface area ranges from about 3,050km^2 in the dry season to 3,600 km^2 at the close of the rainy season, with a perimeter length ranging from 3,000,000 to 3,187,730 m depending on season and rainfall. The lake is about 68 km wide and 73 km long with a previously recorded maximum depth of 14m and average depth of 8.8m. The volume of the lake is some 28,000 km^3 but this depends heavily on the local climate and is also highly influenced by the surface area which exposes it to a high evaporation rate (1,800mm/yr) (Selome Mekonnen, 2006). The alternating dry and rainy seasons result in an average difference of 1.5 to 2 meters between the lowest (May-June) and highest (October-November) lake levels. The lake is the largest freshwater lake in Ethiopia located approximately 563km northwest of Addis Ababa at an altitude of around 1,830m asl.

The shallowness of the lake, together with submersed aggregations of basalt rock formations, make navigation difficult, particularly in the shallower parts of the lake. The relatively shallow depth is thought to be responsible for the low residence time (1.5 years). The lake is the source of a major outlet tributary, namely the Blue Nile River (also called the Abay River). This outlet has an international character as it joins and empties into the White Nile,

[1] Smallest organised village unit in Ethiopia

where its waters are then shared by other partner member states of the Nile Basin Initiative (NBI) especially Sudan and Egypt in the far north of Africa. There are 37 islands in the lake, many of which house ancient Ethiopian Orthodox Christian churches and monasteries generally originating from the 12^{th}-14^{th} centuries. Most of the islands are small; two of the larger islands were historically the seat of Ethiopian Emperors. Daily ferry services transport goods and link major towns around the lake.

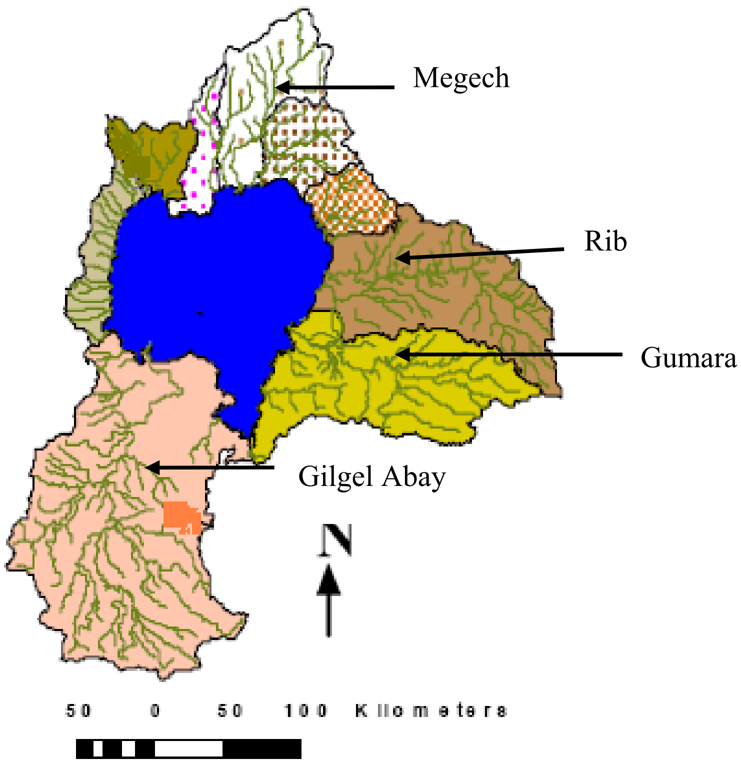


Figure 1.1. Watershed of the LTSB (adopted from Selome Mekonnen, 2006)

The lake is replenished by five large permanent rivers as well as many small seasonal rivers in addition to surface diffuse run-off. The main tributaries to the lake are the Little Nile River (Gilgel Abay), which is the major source originating from the mountains in the south west at 2,850m asl (Selome Bekele, 2006), the Gelda River and Gumara River from the east, the Megache River from the northern region and the Rib River from the north-east. In addition, about 30 or more seasonal and perennial rivers flow into the lake (Figure 1.1). Together they contribute more than 95% of the total annual inflow (Lamb *et al*., 2007). The Blue Nile is the main exit river and flows a distance of 4,750 km to the Mediterranean Sea. Studies show that water from Lake Tana together with the south-western and northern river basin systems of Ethiopia contribute about 86 % of the total waters of the Nile River.

Based on chemical parameters Lake Tana is mesotrophic, but with a low chlorophyll content and primary production by tropical lakes standards (Wondie *et al*., 2007). Its bottom substrate is volcanic basalt mostly covered with a muddy substratum with little organic matter (Howell & Allan, 1994). The lake level has been regulated since the operation of Chara-Chara weir in

1996, which was constructed to regulate the outflow from the lake to the 75 Megawatt Tis Abay II Hydroelectric Power Plant. This power plant is located at the site of the famous Tis Issat waterfalls, some 32 km downstream on the Abay River (Blue Nile), and diverts much of the flow into its turbines. This has compromised one of the most prominent tourist attractions in the area.

The bulk of the Ethiopian highlands where the Lake Tana sub-basin occurs is referred to as an Afro-montane Hotspot (Figure 1.2), and is characterized both by exceptional levels of plant endemism (at least 1,500 species of endemic vascular plants) and serious levels of habitat loss (at least 70 percent of its original habitat has been lost) (IUCN, 2005). In terms of the different designations of African vegetation, the Afro-montane hotspot is a regional centre of endemism, but also an cxtreme centre for floristic impoverishment for various types of Hyparrhenia and other savanna species. The biodiversity of the LTSB is significant in that it marks the northern-most limits of the main plant species in Ethiopia.

Figure 1.2. The Afro-montane Biodiversity Hotspot of Ethiopia (shown in red)

Source: Conservation International website (http://www.biodiversityhotspots.org)

1.2 Origin and Geology of Lake Tana

Lake Tana was originally much larger (Rzoska, 1976) and much deeper (Lamb *et al*., 2007) than it is today. The lake was formed by volcanic activity about 1.8 million years ago that blocked and reversed the previously north-flowing Blue Nile of the early Pleistocene (Mohr, 1962) and created one of Africa's greatest waterfalls, Tis Issat. Geological evidence indicates that these quaternary volcanoes, also called Aden volcanoes or the Aden Volcanic Series, arose from tectonic movements. The volcanic basalt flow filled the exit channel of the Blue Nile River resulting in the present natural dams found in the LTSB.

Recently-collected geophysical and core data show nearly 100 m of accumulated sediments in the lake's bottom substrates (Lamb *et al*., 2007). The bottom of the lake is volcanic basalt covered mostly with a muddy substratum and little organic matter (Howell and Allan, 1994).

In these sediments desiccation layers indicate that the lake dried out at apparent regular intervals during the later stages of the last Ice Age some 10,000-25,000 years ago. The data indicate that Lake Tana dried out completely some time after 18,700 cal BP, when stiff sediments at the base of the core were deposited. Periphytic diatoms and peat at the base of a core from the deepest part of the lake overlie compacted sediments, indicating that desiccation was followed by development of shallow-water environments and papyrus swamp in the central basin between 16,700 and 15,100 cal BP. As the lake level rose, open-water evaporation from the closed lake caused it to become slightly saline, as indicated by halophytic diatoms. An abrupt return to freshwater conditions occurred at 14,750 cal BP, when the lake overflowed into the Blue Nile (Lamb *et al*., 2007). The flood plains of Kunzla, Dembia and Fogera are believed to have been part of the lake, but were deposited by high sediment load during the inter-glacial period where high rates of evaporation took place that reduced the size of lakes throughout the world. The changes that resulted in drying of the lake between 18,700 and 16,700 cal BP is associated with the evolution of its labeobarbs, *Barbus* and *Garra* fish species. The rocky substrates of the littoral zones of the lake provided habitats for keystone non-piscivorous barbus stocks provided refugia, and possibly led to the speciation of piscivorous barbus stocks (De Graaf, 2003). The same is thought to have happened around the same time in Lake Victoria, where a species flock of *Haplochromis* species evolved in a similarly short time (Johnson *et al*., 1996).

The geomorphology of the lake and its associated landscapes and basalt rock formation habitats have been modified by human activities for urbanization and raw material excavations. The most important geologic raw materials that are extracted and the processes that have affected the geomorphology of the area include sand mining and gravel and natural stone excavations. Extraction of these raw materials involves land use change in the landscape and thus causes substantial impairments of the productive capacity of the natural environment and of the scenic qualities of the landscape. Commercial sand mining from the shoreline habitats of the lake and its feeder rivers, and quarry excavations are the foremost anthropogenic activities.

1.3 Climate of the Lake Tana Sub-Basin

1.3.1 Temperature

The LTSB has a climate which is typical of semi-arid regions close to the equator (Gamechu, 1977), with a high diurnal temperature variation between day-time extremes of 30^{o}C to night lows of 6^{o}C. Mean temperatures of 18.5^{o}C have been recorded around Bahir Dar, with a mean maximum of 26.3^{o}C and mean minimum of 10.7^{o}C. The Lake Tana surface water temperature varies between 20.2^{o}C – 26.9^{o}C.

1.3.2 Wind

Winds in Lake Tana are predominantly southerly with a force of 2-3 Beaufort from January to July, and mostly northerly with a force of 2-2.5 Beaufort from August to November (Gasse, 1987). The lake is well-exposed to the winds since it is shallow and is protected by vegetation only on the south-west forested side (Zegie Peninsula). Wind speeds show a pronounced diurnal pattern; during the night and morning wind speed is generally below 1.5 ms^{-1} whilst in the afternoon until the early evening wind speeds are generally between 3.0 and 4.8 ms^{-1}. Although a stable thermocline is lacking (Dejen *et al*., 2004), a thermal stratification of short duration (i.e. several hours) may occur especially during the dry season in the morning. The central part of the lake is highly subjected to winds causing strong wave actions. During the summer, wind-fetched hurricanes/cyclones ("Toro" in Amharic) are seen at times and cause serious destruction. The shoreline wetlands are subject to avalanches, land slides and soil creeps. Wind-fetched wave actions cause regular movement of huge masses of floating islands comprising papyrus and typha stands.

1.3 Rainfall

Rainfall in Lake Tana and its surrounding region is characterized by a unimodal rainfall pattern brought about by wind systems coming from the Indian Ocean combined with those from the Atlantic to give continuous rain or one long rainy season, from March/April to October/November. The area receives light rainfall from March/April to June, from the Indian Ocean, followed by long and heavy rainfall from July to September from the Atlantic Ocean. Rainfall may reach up to 1,750 mm per year falling in one rainy season from May to October with one peak during July-August. The amount of rainfall decreases from south to north (EWNHS, 1996). Rainfall data collected for the 10 year period from 1992-2002 indicate that the monthly maximum rainfall is 449 mm and 358 mm in July and August, respectively (Figure 1.3). Rainfall records in Bahir Dar for the last thirty years (1964-2004) show an average annual rainfall of 1,447 mm, with a maximum of 1,750 mm in 1973 and a minimum of 750 mm in 1991 (Figure 1.4).

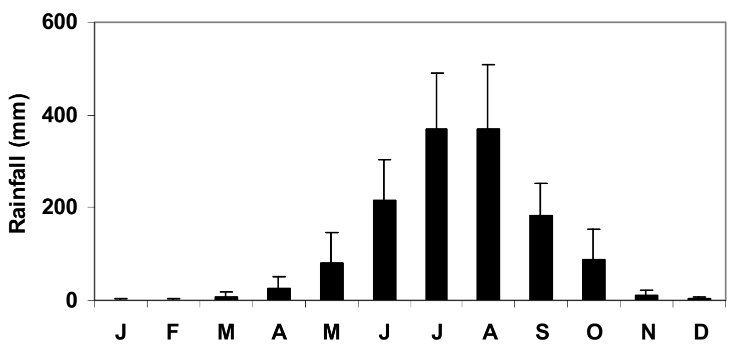


Figure 1.3. Mean monthly rainfall for the 10-year period (1992–2002). Error bars represent 1 SD (Source: Molla and Menelik, 2004)

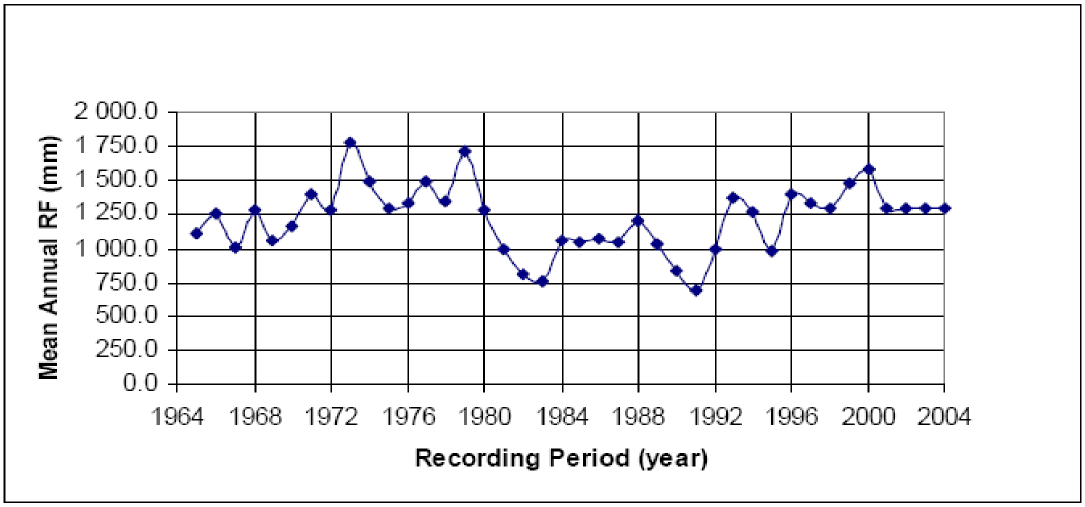


Figure 1.4. Mean annual rainfall record for the Lake Tana area (1964-2004) (Source: Molla and Menelik, 2004)

1.3.4 Evaporation

The total annual inflow of water to the lake is 10.3 x 10^9 m^3/yr and outflow as the Blue Nile River is ca. 36% of this, i.e. 3.7 x 10^9 m^3/yr (Teshale, 2003). This large difference between inflow and outflow is caused mainly by the high evaporation losses. During October to June evaporation exceeds input via rainfall and many of the inflowing streams dry up completely (Molla and Menelik, 2004). The average annual evaporation at the open water body of the lake has been measured as 2,000 mm/year, varying from a maximum of 2,300 mm/year in January and February, to a minimum of 1,800 mm/year in August. The monthly maximum rates of evaporation range from 270 mm in January and February to a minimum of 75 mm in August. In addition, a recently-built dam and 78 MW Power Plant to provide electricity for the country (the plant is connected to the national grid system) are continuously using water from the lake. The water outlets from the lake are currently to the dam and into the Blue Nile. Water-use by the hydroelectric Power Plant is important during the dry season (February-May).

1.3.5 Lake water level changes

The complex pattern of water losses and inputs can cause large daily and seasonal water level fluctuations. Water levels were highest at the end of the main rainy season and during the post-rainy period, slowly decreasing to a minimum around the end of the dry season. The difference between the minimum water level in May-June and the maximum in September-October is generally 1-1.5 m (Figure 1.5). The lake's water levels show a strong variation over time and have decreased so much in recent years that ferries are no longer able to reach the islands.

The surface elevation of Lake Tana has been over-estimated by many authors at 1,830m asl. However, the Ethiopian Mapping Agency recently reported the elevation of the lake to be 1,785m asl (1998) and this elevation is taken as a bench mark for measurement of the water level of the lake. The mean change in water level/fluctuation of the lake is extrapolated to be 1.44 meters (see Figure 1.5). The highest recorded water level was 1,787.53m asl in 1964 with the lowest at 1,784.66m asl in 2003. When the water level of the lake is at its natural elevation, 1,785m asl, the flow volume of the lake is about 16,000 million m^3. Furthermore, the ecological systems of the lake and associated wetlands have been affected by the historic hydrological regime disturbance, the El Niño Southern Oscillation and by the recent human pressures of wetland drainage, water abstractions and other development schemes

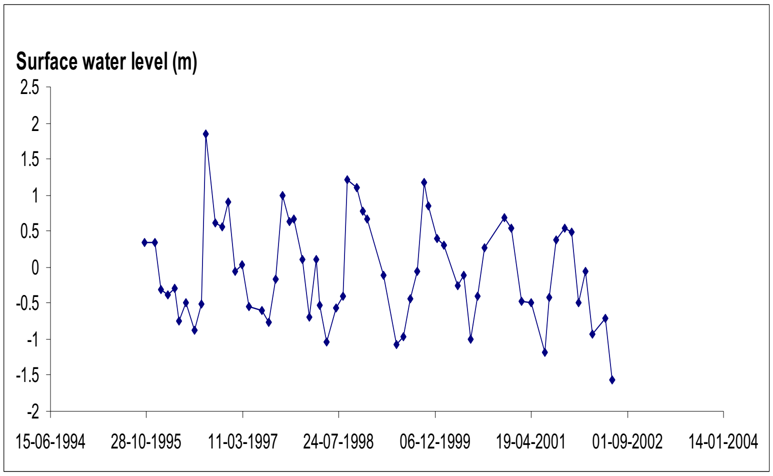


Figure 1.5. Temporal variation of relative surface water levels in Lake Tana (ESA, 2003)

There is a positive correlation between volume, area-size and out-flow discharge of the lake with the waters of the inflowing rivers and streams. The state of rainfall within the LTSB determines the waters that flow into the lake through runoff and inflowing rivers. Data over a 40 year period indicate that the highest inflowing discharge into the lake was 412 m^3/sec in 1964 and the lowest 218 m^3/sec in 1972, with an average of 300 m^3/sec inflow including the waters from rainfalls at the surface of the lake. In the years between 1959 and 1995, the highest out-flow of the Blue Nile River was 204 m^3/sec in 1964 and the lowest 31 m^3/sec in 1985, with an annual average of 114 m^3/sec. At the time of the drought years in the 1970s and 1980s, the maximum and minimum out-flows were 305 m^3/sec and 10 m^3/sec, respectively.

1.4 Wetlands and the Hydrology of Lake Tana

The major water sources of Lake Tana are from surface water, rainfall and ground water recharge due to the presence of extensive surrounding wetlands. The extent of the discharge and recharge functions of the Tana wetlands has not been studied. During the wet season, Lake Tana is fed by over sixty rivers and streams, but year-round it is fed by six permanent rivers: the Gilgel Abay, Gumera, Rib, Megech, Gelda and Enfranz Rivers. The total area of the largest rivers draining into Lake Tana (Gilgel Abay, Gumera, Rib and Megech) is 5,112 km^2, an area quite feasible in size to concentrate management efforts, compared to the larger sub-basin area of 16,500 km^2, where the drainage is a diffuse runoff.

The lake is bordered by low-lying plains wetlands in the north (Dembea), east (Fogera) and south-west (Kunzila) that are often flooded in the rainy season and by steep rocks in the west and north-west. The wetlands are located all around the lake, with the exception of the north-east. Together, the wetlands are the largest in the country and comprise integral parts of the complex Lake Tana ecosystem. Consisting of permanent swamps, seasonal swamps and areas subjected to inundation, during the rainy period these wetlands are connected to the lake and are considered to act as nurseries for most of the fish populations in the lake. They also serve as breeding grounds for water fowl and mammals. About 8 of the 15 *Labeobarbus* species and three other commercially important fish species, ie, the Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and beso (*Varicorhinus beso*) spawn in the wetlands and their juveniles spend the first years of their life feeding and growing in the wetlands.

The littoral region of the eastern and southern part of the lake is dominated by papyrus reed *Cyperus papyrus*, common bulrush *Typha latifolia* and common reed *Phragmites karaka* , whereas the snake root *Persicaria senegalensis* , hippo grass *Vossia cuspidata*, other bulrushes (*Scirpus* spp.) and the tiger lotus (or water-lily) *Nymphaea lotus* are common (Muluneh, 2005). In the open water of the inshore zone the common hornwort *Ceratophyllum demersum* and tape or eel grass *Vallisneria spiralis* are the most abundant species. These wetlands are important resources that supply essential raw materials such as fire wood, common reeds (typha, phragmites) and papyrus. When the lake level drops during the dry season hundreds of square kilometres of lake-bottom become available for agriculture and are used by the farmers to grow crops. The wetlands around the southern bay of Bahir Dar alone cover ca. 1,170 km^2. These wetlands have water for about 4 months and it is the country's largest rice production area. The livelihood of some 3,000 Negada ethnic groups is totally dependent on the wetland products.

The subsequent chapters attempt to describe the role of the existing wetlands, biodiversity and water resources in sustainable development of the Lake Tana sub-basin which has not previously been documented.

1.5 Land-use patterns of the Lake Tana Sub-Basin

The map of the Lake Tana sub-basin was compiled from digital data on topography, towns, roads and rivers of the country made at 1:1,000,000 scale and the elevation contour lines at 100 m interval. The elevation map was converted to Digital Elevation Model (DEM) using ArcGIS 9.1 to obtain a three dimensional perspective. The GPS coordinates of the sampling sites were overlaid on the DEM to indicate the land-use and sampling localities considered by the relevant disciplines of the study.

The land-use pattern of the LTSB depicts an area which is heavily populated and cultivated and the different land-use types are shown in Figure 1.6 (Alemayehu, 2006). Different crop types are produced in the various agro-climatic conditions with cereal production the dominant use of the cultivated area. Due to this land-use pattern, soil erosion is inevitable and appears to be one of the biggest problems in the area in terms of siltation of Lake Tana. Watershed management must be put in place as a priority programme before it becomes too late. The direct manifestations of land degradation, such as forest clearance, overgrazing, erosion, siltation and loss of soil fertility have already been the subject of much analytical research with inadequate application of many technical solutions. However, neither the indirect impacts nor the root causes of land degradation have had the same level of analysis.

The concept of ecotone implies that the response of vegetation formations to environment is depicted through their occurrence along a trajectory. This assumption holds true when ecosystems are not fragmented, an assumption that is automatically ruled out in the LTSB which is an anthropogenic landscape highly influenced by a long history of land use. Non-irrigated cultivation is several-fold higher than irrigated cultivation and could be expected to remain so considering the low level of development of the sector. However, current developments in the LTSB could increase irrigable area to more than 134,670 ha, as shown in Table 1.1 below (Sileshi *et al.*, 2007). Expansion of Bahir Dar and other cities in the Amhara Region is putting pressure on natural resources and land with resultant compromises for biodiversity conservation and food security. The major industries claiming land on the shores of Lake Tana include hotels, food factories, a textile factory, and two tanneries; in each case there has been poor integration of environmental concerns with development needs.

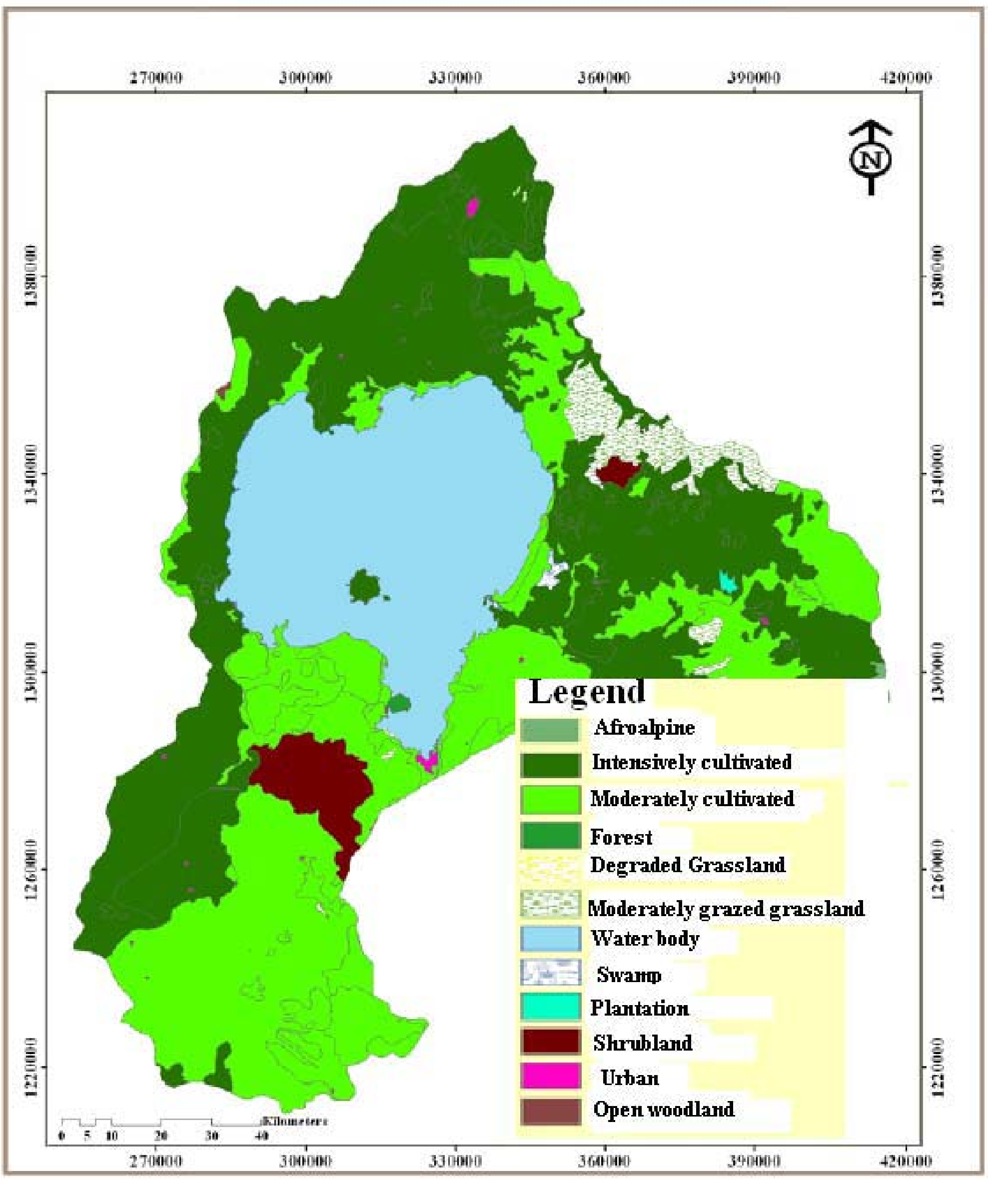


Figure 1.6. Land use and land cover of the Lake Tana sub-basin (Alemayehu, 2006)

Table 1.1. Potential irrigable land in ha in the watershed in LTSB (Sileshi *et al*., 2007).

Watershed	**Small**	**Medium**	**Large**	**Total**
Gilgel Abay	1,025	15,353	0	16,378
Gumara	0	6,966	9,475	16,441
Megech	0	3,030	5,570	8,600
Rib	0	6,430	17,010	23,440
Tana	500	27,167	42,144	69,811
Total	**1,525**	**58,946**	**74,199**	**134,670**

It is important to note that the situation as represented in the above land-use map could have already changed due to the rampant deforestation and visibly over-exploitation of the natural vegetation cover that are continuing with little regulation. It is important that measures are put in place to enhance proper management of the natural resources in order that they can contribute sustainably to people's livelihoods.

1.6 Livelihood strategies

The people in the Lake Tana sub-basin earn their livings from several sources, both agricultural and non-agricultural. During the year 2007, a majority of the people (about 90%) earned their living from crop production coupled with livestock production. About 28% of the households generated income from sales of firewood and charcoal. From an environmental point of view, dependence on income generation from forest products sends an important signal of potential forest degradation.

The average *per capita* income during the year 2007 was Birr 2,600 (approximately US$ 260). Crop production accounted for 60% of the household income followed by livestock, which contributed about 13%. Fishery and other non-farm activities contributed about 10% of the household income each whilst sales of trees and fire-wood accounted for 7% of the household income. Assuming a consumption need of US$ 1 per day per person, the sample respondents could provide food for the household for about 10 months only.

1.7 Impacts of Current Land-Use Practices

- *Erosion and silt load*

During the last 20-30 years deforestation has become common practice in the Lake Tana catchment area and has caused massive soil erosion. The catchment area of approximately 16,500 km^2 has a dendritic drainage network. Due to this type of drainage, its scanty vegetation and high rainfall during short periods in the main rainy season, the soil loss rate from areas around the lake is high (31-50 tonnes ha^{-1}/yr) and has shown a substantial increase during recent years. Soil loss rates are especially high in the eastern part of the lake, i.e. 5-250 tonnes ha^{-1}/yr, and lowest on the western side of the lake due to its low catchment and vegetation cover (Teshale *et al*., 2001, Teshale, 2003).

During the main rainy season (July-August) the four major inflowing rivers carry heavy loads of suspended silt into the lake, thereby increasing the turbidity of the lake water (Wondie *et al*., 2007). The suspended sediments reduce the under-water light regime and reduce the primary production, the basis of the food web. In general the land-use system in the Lake Tana sub-basin has changed dramatically within a short period, noticeably towards intensive cultivation.

1.2 Soil erosion from rivers

There is no adequate data and information on soil erosion rates basin-wide to provide reliable information on soil loss rates and impacts on the ecology of the lake at this time. The data for the last eight years on sediment transportation of four major permanent rivers was reviewed and is presented here to supplement the state of soil erosion and sedimentation in the lake.

It must be noted that the data collected to understand the dynamic change of soil erosion rates are not recent, although they are useful to provide baseline information on the state of soil erosion rates. Inevitably, given the high human population density and continued land-use changes resulting from uncontrolled land fragmentation and intensive use of sub-land division and deforestation, soil erosion is bound to increase at an alarming rate even in the near future.

According to the Ministry of Agriculture (1984), soil erosion rates have been estimated between less than 5 to more than 250 tonnes/ha^{-1}/yr (Berhanu *et al*., 2001). This must surely have increased by a considerable percentage as muddy-brown chocolate rivers and run-offs are, observed during the rains – an indication that soil erosion is very high.

Four major environmental variables that affect soil loss/erosion rates have been recognized, including topographic gradients/slopes, vegetation cover, rainfall intensity and soil type/nature (erodibility and corrodibility).

The contribution of the major influent rivers of Lake Tana to the sediment loading is presented in Table 1.2.

Table 1.2 Soil Erosion of the major permanent rivers of Lake Tana and Blue Nile River around Bahir Dar (1980-1992)

Year (E.C)	**Gilgel Abay**	**Gumara**	**Rib**	**Megech**	**Total sediment load (ton/yr)**	**Abay at Bahir Dar**
1980	3347.8	1163.3		239.9	4751	1
1981	3520.5	1332		174.1	5026.6	1
1982	2922.5	720.7	717.5	32.7	4393.4	
1983	2414.6	1340.3		104.8	3859.7	0.6
1984	2756	1076.6	290.5	403.2	4526.3	0.3
1985	3238.2	2684.9		465.1	6388.2	0.9
1986	1959.2	1861.7	1.9	516.7	4339.5	1.1
1987	2308.4	1422.9	0.3	101.3	3832.9	0.8
1988	2900.7	3663.9	1.9	569.7	7136.2	2.3
1989	3249.9	2200.5	0.6	186.6	5637.6	1.3
1990	2080.4	2763.2	0.8	136.5	4980.9	0.8
1991	3295.6	2635.5		255	6186.1	

Year (E.C)	Gilgel Abay	Gumara	Rib	Megech	Total sediment load (ton/yr)	Abay at Bahir Dar
1992	2678.5	2318.3	2.7	297.1	5296.6	1.4
catchment area (km^2)	1664	1394	1592	462	15321	

Source: EPLAUA (various dates)

Gilgel Abay (Little Abay) River is the largest and longest of all ephemeral and perennial feeder rivers with an estimated sub-basin area of 1,664 km^2. This river is stretched southward of its catchments and flows north-west and then northward, emptying its high sediment loads into Lake Tana with an annual average of 2,660.1 tons/year. It originates from Sekela Woreda and cascades down from a gentle sloping plain to flat plain topographic features.

The second erosive and longest river is Gumara with an average sediment load of 1,937.11 tons/year. This river has an area of 1,394 km^2 sub-basin and starts from Mount Guna (4,150m asl). The major landscapes of the sub-basin include mountains, undulating to rolling plains and flat plains. The third erosive river, which carries high sediment loads, is Megech River with an annual average sediment load of 267.9 tons/year and with an area of 462 km^2 sub-basin. The fourth least-erosive river, but with the second largest sub-basin area of 1,592 km^2, is Rib River with an average soil sediment load of 127 tons/year (eight years data). There is no data on the state of soil erosion rates of the other perennial and seasonal rivers and streams, but a high sediment load is expected to enter into the lake. Taking into account the missing data of the Rib River (see Table 1.2), an average of more than 5,000 tons/year sediment is extrapolated to enter into Lake Tana from these four major inflowing rivers.

As can be seen from the above table, the sediment load of the Blue Nile (Abay) River at Bahir Dar is low (< 1%) compared to the inflowing rivers. This indicates that some of the transported high sediment loads is deposited and silted down in the water body of the lake. Thus, it can be said that Lake Tana functions as both a natural water reservoir and a silt refinery for the Blue Nile River. However, the latter function is detrimental to the long term existence of the lake and its service as a habitat for aquatic organisms. Accordingly, protection of the wetlands, which act as natural filters, is very important because much of the silt load into the lake is through the diffuse non-measurable inputs of the wider catchment area rather than the rivers per se. An assessment of the silt load from the catchment areas rather than the rivers is strongly recommended.

1.3 Soil erosion from lake catchment

With a catchment area of about 16,500 km^2 and a lake area of 3,200 km^2, Lake Tana has a drainage ratio (CA:LA) of 5.2. This is only double the ratio of Lake Victoria in central Africa (CA:LA of 2.6), which has almost 20 times more surface area (62,940 km^2) and slightly larger than Lake Malawi (3.0), which has 7 times more surface area (22,490 km^2). Lake Tana has the lowest drainage ratio of all Ethiopian lakes, although it is the largest in size and constitutes over 50% of the lake area of the country.

The implications of the low drainage ratio on many limnological parameters are discussed in Chapter 2 of this book.

The mean water residence time (WRT) of Lake Tana is comparatively much lower than most lakes of similar drainage ratios, indicating that the lake behaves more like a reservoir than an open (exhorreic) lake. The WRT of Lake Tana has been drastically reduced in recent years due to a combination of natural factors (ie silt build-up in the lake) and accelerated by human activities that enhance erosion and catchment degradation. For example, Rzoska (1976) reported the WRT of Lake Tana as 6.5 years. Recent modeling and some empirical measurements indicate than the WRT has been reduced to 1.6 years.

Large catchments receive more sediments than those in small drainage basins. However, the sediment yield per unit area (also called export coefficient) is higher for smaller basins as a result of greater sediment trapping by large, low-slope basins. This is true especially for cultivated catchments. According to the regression line in Dearing and Foster (1993), a CA:LA ratio of 5.2 gives a sediment yield of ~100 tons km^{-2}/yr for cultivated catchments such as the Lake Tana sub-basin. This implies an average of 1.5 tons/km^2 annual deposition of sediment in Lake Tana and, further, that Lake Tana has been acting as a silt refinery and has amassed loads of sediment. This sediment has gradually filled a considerable portion of the lake basin, which in turn has shaped its morphometry and sloping from west to east.

Despite considerable retention of sediment in the lake bed, a small portion is exported out through the Blue Nile (Table 1.2). This has been an opportunity and a threat to downstream riparian ecosystems for a long time. Small steep catchments deliver more sediment with adsorbed nutrients (Mahon, 1984). High sediment loads and associated nutrient exports from intensely farmed catchments can have a deleterious effect in shallow lakes, causing algal blooms (Roth, 1994) and general eutrophication. The intensification of animal husbandry in the LTSB has been taking place over a long historical period and it is not hard to imagine high organic nutrient loading in the catchment; consequently, the nutrient concentration levels in the upper catchments of the LTSB were found to be very high. Agricultural intensification in the catchments has therefore exacerbated the eutrophication trend in Lake Tana. This is manifested by seasonal blooms of green algae at the end of the post rainy months, when fishermen find it difficult to operate their nets as they clog with mats of green alga scum. The high nutrient loading into Lake Tana, enhanced by its low drainage ratio, could also have dire consequences if floating macrophytes such as the water hyacinth become established in the lake. The Nile cabbage, *Pistia stratiotes*, is already present in the lake, but not in large or nuisance levels.

1.7.4 Reed harvesting

The removal of reeds through harvesting and fires, to detract wild pigs, have become serious problems in the Lake Tana area. People remove Typha and Cyperus stands for religious ceremonies, boat-building, roof-thatching and other purposes. There is a need for control mechanisms to be applied to ensure sustainability of this valuable resource. The long-term effects of such actions include the following:

- increased bank erosion and bank instability
- increased sediment scouring and loading into the lake
- submerged macrophytes may increase as a result of reduced competition from emergent forms and from improved nutrient drainage in the littoral zone
- submerged macrophytes may trap more sediments and enhance primary production by the periphyton algae
- eutrophication due to organic matter loading from macrophyte decomposition

- infestation and surface increment by submerged macrophytes may enhance lake fill-up and change of littoral into dry land - a phenomenon witnessed by local communities over the last few decades
- due to high human and livestock population pressure, farmers are encroaching into the lake shores and wetlands, thereby seriously compromising the ecological integrity of both. This is particularly evident in the eastern catchment where farming takes place right up to the shoreline and excessive reed removal and grazing have already left their marks in the form of a degraded landscape and abandoned fields.

1.8 Threats to Lake Tana and its catchment

The threats in the LTSB are multiple and interlinked but are listed here under just two general sub-headings:

1.8.1 Socio-economic factors

People exploit the natural resources as a means of survival. This is putting pressure on the few remaining patches of the already impoverished forests and meadows, which may succumb to further conversion to agriculture given the lack of alternatives. In the process, biodiversity is being lost, wetlands are drained and products such as papyrus and grasses are harvested for domestic purposes. These activites are enhancing sediment deposition around the alluvial plains and the sloping landscape.

The expansion and urbanization of Bahir Dar into the southern shore of Lake Tana could repeat itself on all sides, as already noted in nearby towns such as Delgi. Although vital to ensure water security, large-scale dam constructions need to be well-planned to mitigate against their hydrological, ecological and social implications in the sub-basin over the short and long-term.

1.8.2 Institutional and policy problems

The development activities around the Lake Tana sub-basin fall under different regimes and mandates that are not coordinated under one roof. This is to the detriment of biodiversity conservation, which puts the protection of biodiversity and habitat loss at a risk since it does not appear as a priority to decision makers and communities living around them.

At the institutional and policy level, there seems to be inadequate technical and human resources capacity, as well as a lack of wetlands policy and management strategies to reverse the trend of degradation whilst permitting sustainable use of the lake and wetlands resources.

The current land-use tenure system enhances and compounds degradation problems as farmers who do not own their own land have little incentive to plant trees and perform conservation activities on the property.

In the case of the LTSB, there is need for an institution to carry out the following functions:

- Coordinate stakeholders and involve local resource users and stakeholders in the management of the sub-basin
- Implement policy on wetlands and biodiversity management to harmonise the mandates between departments of water resources, agriculture and environment

- Act on behalf of a competent and responsible lead agency to address wetland and biodiversity issues in the sub-basin
- Oversee control of soil water conservation methods
- Contribute to the technical capacity for land-use planning and integrated ecosystem/watershed management

In the absence of such an institution, the following threats to the LTSB will prevail:

- Hydrological disruptions or hydrological regime/water level disturbance due to water withdrawals and poor water management in the lake and its catchment
- Decline in water quality and quantity due to water pollution and eutrophication from point sources due to increased urbanization and deposition of fertile nutrients into the lake shore
- Loss of pasture due to increased livestock numbers and land degradation
- Invasions of alien plant species and decline in biodiversity numbers
- Long-term siltation/sediment deposition by rivers, wetlands and alteration of the alluvial plains in the sub-basin

Other factors include global climatic changes and the recurrence of a series of droughts over the last several hundred years. Even though no scientific documentation has been made on the deleterious effects to the lake's ecological systems caused by climatic changes, the overall ecological integrity of the lake has largely suffered from the events of El Niño Southern Oscillation[2] and La Niña[3]. The fact is that since Ethiopia is located in the tropical monsoon belt, the climatic conditions of the lake's system in particular and the country in general have been affected by the Southern Pacific Oscillation's highly dynamic large scale weather systems, created by variations in sea surface temperature and barometric pressure across the Pacific and Indian Oceans.

The Nile River and the riparian communities of Lake Tana sub-basin are also believed to be highly impacted by climate changes. Of the world's major rivers, the Nile has the lowest specific discharge (i.e., flow per unit catchment area), even if only the part of the catchment that receives precipitation is considered (Reibsame *et al*., 1995). Furthermore, because this river originates within the tropics, where temperatures are high, evaporative losses also are high in comparison to rivers in temperate regions. Elevated temperatures will enhance evaporative losses and unless they are compensated for by increased precipitation, run-off is likely to be further reduced. All these anticipated impacts are compounded and accelerated by intense anthropogenic pressure in the Lake Tana sub-basin.

---

[2] The **El Niño Southern Oscillation** is a highly dynamic, large scale weather system that involves variation in sea surface temperature and barometric pressure across the Pacific and Indian Oceans, which affects the climate system of North America, Australia, Southern Asia, Africa and parts of southern Europe. At the mature phase of an El Nino, the climate of Ethiopia is entirely affected causing drastic effects on its ecological systems and people by severe droughts.

[3] ***La Niña*** is the extreme opposite of an El Niño and occurs in periods of lower sea surface temperature and higher than average barometric pressure in the eastern tropical Pacific Ocean. During this period, Ethiopia receives unusual precipitations and suffers drastic storms and runoff.

1.9 Stakeholders and Institutions in managing the Lake Tana Sub-Basin

1.9.1 Institutions

The management of Lake Tana and its sub-basin is a shared responsibility with unclear mechanisms to coordinate the relevant stakeholders in its management. The following are the main institutions involved in the management of the LTSB:

(i) at the federal (national) level, the public institutions involved in water resources development include:

- The Ministry of Water Resources (MoWR) - responsible for the overall planning, development, management, utilization and protection of the country's water resources, as well as supervising all water development activities carried out by other institutions. Large-scale water supply is also handled by the ministry through its Water Supply and Sewerage Department
- The Ministry of Agriculture and Rural development (MoARD) - in charge of water management (irrigation extension), including water harvesting for smallholder irrigated and rain-fed agriculture
- The Environmental Protection Authority (EPA) - responsible for the preparation of environmental protection policy, laws and directives. It is also in charge of evaluating the impact of social and economic development projects, particularly irrigation and hydropower projects, on the environment and is further responsible for follow-up work.

(ii) at the regional/sub-national level, the institutions involved in the water sector include:

- The Bureaus of Water, Mines and Energy (BoWME) and/or Bureaus of Water Resources Development (BoWRD), which exist in some regions - responsible for small-scale irrigation and rural water supply as well as small-scale hydropower development
- The Irrigation Development Authorities (IDA) - undertake operational activities in line with their mandates (study, design and construction of small-scale irrigation schemes)
- The Bureaus of Agriculture (BoA) - have similar functions to the MoA but at the regional level

Several NGOs are involved in the water sector, particularly in small-scale irrigation and rural water supply projects.

1.9.2 Water management

Medium and large-scale irrigation schemes are managed by government enterprises. The water management of small-scale irrigation schemes is the responsibility of the farmers themselves, mainly through informal/traditional community groups. Some formal Water Users Associations (WUAs) exist to provide extension and training services on behalf of the MoA/BoA.

A Water Resources Development Fund (WRDF) has been established recently within the MoWR to serve as a public financial intermediary dedicated to financing water supply and sanitation services as well as irrigation development through the provision of long-term loans to groups that meet established criteria. The loans are based on the principles of cost recovery.

A comprehensive and integrated Water Resources Management Policy, prepared by the MoWR, was adopted in 2000. Some of the guiding principles are: i) recognition of water as a scarce and vital socio-economic resource to be managed and planned strategically; ii) recognition of water as an economic good; iii) stakeholders to be involved in water resources management.

1.9.3 Legislation and Policy issues

Relevant proclamations for the water sector include:

- Proclamation No. 197/2000, stating that all of the country's water resources are the common property of the Ethiopian people and the state and giving the MoWR the necessary power to allocate and apportion water to all regional states regardless of the source and location of the resource
- Proclamation No. 4/1995, stating that the MoWR has the power and duty to determine the conditions and methods required for the optimum allocation and utilization of the water that flows across or between more than one regional government among various users
- Proclamation No. 41/1993, granting the regions the mandate for certain aspects of water resource management, including small-scale hydropower activities
- Proclamation No. 197/1992, dealing with the water resources management regulations describing development areas that require a license, procedures for obtaining licenses, the allocation of water for various uses and the need to protect water resources from pollution. It considers that water is an economic good and that it has to be valued and deserves protection. A water code is being drafted.

1.9.4 Lake Tana institutional factors

According to the Constitution of the Federal Government, trans-boundary lakes and rivers of the country are managed in terms of a federal administrative framework; Lake Tana and its feeder rivers are no exception. However, different tiers of government institutions are responsible for water issues at lower levels as highlighted below.

(i) Governmental Institutions:

At the federal level these include the Council of Ministers and Parliament, Science and Technology Commission, Ministry of Agriculture and Rural Development, Environmental Protection Authority, Ethiopian Agricultural Research Organization, Ministry of Water Resource, Institute of Biodiversity and Research, Ethiopian Wildlife and Natural History Society, Ethiopian Wildlife Conservation Organization, Ethiopian Light and Power Authority, Addis Ababa University and Ministry of Culture and Tourism.

At the regional level, line bureaus and authorities include: Regional Council, Bureau of Agriculture and Rural Development, Amhara Regional Agricultural Research Institute, Bahir Dar Fishery and Other Aquatic Life Research Institute, Bureau of Water Resource, Bureau of

Youth, Culture and Sport, Bureau of Culture and Tourism, Investment Office, Parks Development and Protection Authority, Environmental Protection, Land Administration and Use Authority, Agency of Cooperative and Promotion, Bahir Dar Municipality Office, Bahir Dar Administration and Public Service Office, Tana Bahir Transport Enterprise, Bureau of Justice and responsible Woreda[4] Councils, Woreda Agriculture and Rural Development Office, Woreda Justice, etc.

(ii) Civil Society Organizations are represented by fishermen associations, traditional church institutions, development committees, CBOs, co-operatives, private enterprises, tourist guides, groups of reed harvesters, Kebele Land Administration, Clean and Green Bahir Dar Professional Association, Amhara Region Youth Association, Amhara Region Women Association and Abay Dar Car Wash Youth Association. The operations of CSOs are usually supported by development partners.

(iii) Religious/Traditional Institutions can play key roles in resource management, particularly in buffer zone management of protected areas. They include churches, traditional healers, CBOs etc. The traditional religious institutions found within and around Lake Tana have played an important role in forestry conservation and management. It is important to recognize this contribution by strengthening their involvement in resource management and development. Of the traditional forestry and/or natural resource management approaches, two forms of religious forestry conservation and management approaches associated with the Orthodox religion were identified: (a) Atsed Forestry and (b) Consecrated Forestry.

(iv) External Support Agencies - these include bilateral and multilateral organizations that play a role in local and regional development as well as support organizations from international NGOs, which through partnership arrangements are more affiliated with local organizations in civil societies. These organizations normally act with fairly different concerns ranging from a fundamental nature conservation perspective to a poverty-oriented development perspective. These include UNDP, GEF, GTZ, SWISSA, SIDA, RWSED, ILDP, ILRI, Ramsar Program, UNESCO, WWF, BLI and ODAs (Organization of Development Agencies).

Ethiopia has ratified most of the Conventions and Agreements relating to biodiversity conservation such as CITES (1989), Convention on Biological Diversity (1992), the Cartagena Protocol on Bio-safety (2005), and the International Plant Protection Convention (1977). Ethiopia is a member of the World Heritage Convention and a signatory to the Lusaka Agreement. However, signing the Ramsar Convention is long overdue as Lake Tana tops the list of wetlands of international importance.

This sub-basin also has a total of four Important Bird Areas (IBAs), namely:

- Bahir Dar-Lake Tana at 11^{o}37'N, 37^{o}25' E
- Fogera Plains on the east of Lake Tana situated at 11^{o}53'-12^{o}02'N and 37^{o}30'-37^o 55'E,
- Mid-Abay (Blue Nile) River Basin located at 7^{o}44'-12^{o}46'N and
- Semien Mountains National Park, located at 13 ^{o} 10'N 38 ^{o} 10'E. The mountains are a World Heritage Site and include the gazetted National Park and are

[4] In Ethiopia, a Woreda is an administrative unit at a lower government level

situated on the northern edge of the central plateau, about 132 km from Gondar town.

Alemayehu Abebe, 2006. GIS Application in suitability modeling for Livestock Production in Tana sub basin- Blue Nile River Basin. A thesis submitted to the School of Graduate Studies of Addis Ababa University in the partial fulfillment of the requirements for the Degree of Master of Science in GIS and Remote Sensing.

Dearing, J.A. and Foster,, I.D.L. (1993) Lake sediments and geomorphological processes: Some thoughts. pp 5-14. In. J. McManus and R.W. Duck (eds.) *Geomorphology and sedimentology of lake reservoirs.* New York, John Wiley and Sons.

de Graaf, M., (2003). Lake Tana's piscivorous *Barbus* (Cyprinidae, Ethiopia): Ecology, Evolution, Exploitation. Ph.D. thesis Wageningen University, The Netherlands.

Dejen E, Vijverberg J, Nagelkerke LAJ, Sibbing F.A. (2004). Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake (L. Tana, Ethiopia). *Hydrobiologia* 513: 39-49.

Gasse, F. 1997. Ethiopie et Djibouti. In African wetlands and shallow water bodies.M.J. Burgis and J.J. Symoens (eds.). Travaux et documents/ Institut Francais de Recherche Scientifique pour le Development en cooperation no. 211 Paris, ORSTOM: 300-311.

Getahun, A, Dejen E & Atenah W. 2008. Fishery studies of Ribb River, Lake Tana Basin, Ethiopia. Final Report. E1573. Volume 2. Addis Ababa, Ethiopia. 126pp.

Howell, P.O. and Allan, P (1994) *The Nile: Sharing a scarce resource*. Cambridge University Press.

IUCN, 2005. The Red List of Endemic trees and shrubs of Ethiopia and Eritrea, Jose Juis Vivero, Ensermu Kelbessa and sebsebe Demissew, Gorgina Magin and Sara Oldfield (eds), Fauna and Flora Red List International.

Lamb, H.F., Bates, C.R., Coombes, P.V., Marschall, M.H., Umer, M., Davies, S.J. & Dejen, E. 2007. Late Pleistocene dessication of Lake Tana, source of the Blue Nile. *Quaternary Research* 287-299.

Mahon, R. (1984) Divergent structure in fish taxocenes of North Tamperate streams. *Can. J.Fish. Aquat. Sci* 56:329-347.

Mohr, P.A. (1962). *The geology of Ethiopia*. Addis Ababa. University college of Addis Ababa press. 268 pp.

Molla, M. and T. Menelik, (2004). Environmental Impact Assesment for Unusual Reduced Water Level of Lake Tana. In Proceedings of the Symposium on Lake Tana watershed management. Lake Net, USA: 35-48.

Muluneh, A,A. (2005) Ecological importance of aquatic macrophytes in the southern part of Lake Tana. Report of the Amhara National Region Rehabilitation Development Organization (TIRET)

Reibsame

Rzoska, J. (1976). *Lake Tana, headwater of the Blue Nile. In the Nile, Biology of an ancient river* (Rzoska, J. ed.) The Hague, Dr. W. Junk publishers.

Seleshi Bekele ,Aster Denekew ,Makonnen Loulseged, Willibald Loiskandl Mekonnen Ayana, Tena Alamirew, 2007. Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123)

Selome Mekonnen, 2006, Assessment of temporal hydrological variation due to land use changes using remote sensing/GIS: A case study of Lake Tana Basin. KTH

Teshale, B., R. Lee & Zawdie, G. 2001. Development initiatives and challenges for sustainable resource management and livelihood in the Lake Tana region of Northern Ethiopia. In Dixon, A. B., A. Hailu & A. P. Wood (eds.), Proceedings of the wetland awareness creation and activity identification workshop in Amhara National Regional State. January 23 rd 2001 Bahar Dar, Ethiopia: 33-43.

Wondie A, S. Mengistu, Vijverberg, J. and Eshete Dejen (2007). Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and water transparency. *Aquat. Ecol*. 41: 195-207.

Wudneh T. 1998. Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia, Ph.D Thesis. Wageningen, Wageningen Agricultural University. 150 p.

Forested catchment – Zege peninsula

Lake Tana seen from Bahir Dar shore

Lake Tana

Tis Issat Falls during the dry season

Fishery research station (Bahir Dar)

Note: Photos taken in January 2008

THE LIMNOLOGY OF LAKE TANA

Seyoum Mengistou
Addis Ababa University
PO Box 32378 Addis Ababa
seyoumen@yahoo.com

2. Introduction

The limnology of Lake Tana was first studied by colonial expeditions in Ethiopia in the early 1900s, and the first bathymetric map of the lake was made by Morandini in 1940. The deepest part of the lake was 14m to the north of Dek Island. Rzoska (1976) stated that the Lake Tana area is characterized by a daytime temperature of 23-30^oC and a night temperature of 6-8^oC, although experiences since then have shown daytime temperatures exceed this range and low night temperatures are rarely encountered, which lends some support to the warming trend in the Lake Tana area in particular, and the country in general. The implication of this global warming trend and the frequency of the *El Niño* phenomenon in Ethiopia, and their probable impacts on the wetlands and Lake Tana is discussed in Chapter 1 and in subsequent chapters of this book.

Few limnological studies have been undertaken in Lake Tana since these early records. Talling (1964) reports some light measurements and stated that the euphotic depth was approximately 3m, much deeper than the maximum value of 1.6 m recorded in recent measurements (Wondie *et al*., 2007). This is further evidence that the turbidity of Lake Tana has increased significantly in the last 50 years.

More studies have been done on the fisheries than the limnology. The PhD studies of Wudneh (1998), Nagelkerke (1999), de Graaf (2003) and Dejen (2003) all dealt with fisheries and evolutionary fish biology. However, they also contain some information on the plankton composition and biomass in Lake Tana. From these, and other unpublished data, it is concluded that the phytoplankton composition in Lake Tana is diverse, but primary production is among the lowest of many African lakes. Nevertheless, algal production can be high in the inshore zone, probably due to daily deep-water column mixing, sediment re-suspension and enhanced nutrient recycling. In general, some authors conclude that energy transfer from algae to the second trophic level is poor, because most of the primary production is realized in only two months (post-rainy season) of the year (Wondie *et al*., 2007; Wondie & Seyoum, 2006).

Practically no information is available on the benthos of Lake Tana. Morandini (1940) reported that the lake bottom has a gentle slope covered with soft sediments. Rzoska (1976) reports that the benthos is poor, without specifying why or how. However, Wondie (2006) reported that the zoobenthos in Lake Tana consists of insect larva such as Chironomidae, Ephemeroptera and Odonata, oligochaetes, mollusks (bivalves and gastropods), macro-crustaceans (crabs) and ostracods, but gave no description of their taxonomy. More detailed studies on the benthos of Lake Tana are required, especially in view of the fact that macro-invertebrates are useful as food for many fish in the lake, and can also be used to indicate the past ecological condition of the lake, and to show some recent trends in water quality of the lake in events of pollution, eutrophication, and siltation due to human influences.

The general objective of this section of study was to appraise the limnology of the Lake Tana based on a literature review and compare it with recent information in order to describe the current situation so as to devise strategic management actions for the lake, its wetlands and catchment. The specific objectives of this study included:

- comparing the current limnological status of Lake Tana with previous reports;
- documentation of the limnological condition of the lake with respect to physico-chemical parameters and nutrients;
- listing the species composition of the phytoplankton, zooplankton, zoobenthos, fish and macrophytes of Lake Tana;
- provide an account of the productivity rates of algae, zooplankton, fish and benthos in Lake Tana;
- prepare a generic food web scenario for Lake Tana and discuss possible ways of maximizing energy conversion efficiency in the system;
- give an account of the water quality and wetlands management of the lake and its sub-basin.

2.1 Methods

Sampling and a literature review were the main methods used to collect data to address the above objectives. Securing secondary data from water and meteorology institutions as well as interviewing main stakeholder institutions were also carried out.

2.1.1 Literature review

The main method used was a literature review of the limnological studies carried out on Lake Tana. Some detailed recent studies included Wondie (2006), Wondie & Seyoum (2006) and Wondie *et al*., (2007). When describing the seasonal dynamics of the phyto- and zoo-plankton communities, the same category of grouping of months used by Wudneh (1998) for fish distribution analysis was applied, with the following minor modifications:

1. Dry season (Dec-April) – low water temperature and high water transparency;
2. Pre-rainy season (May-June) – low water level, high water temperature, higher wind mixing, months of small rains;
3. Rainy season (July-Sept) – heavy rains, high water turbidity, increasing water level; and
4. Post-rainy season (Oct-Nov) – end of rainy season, highest water level and uniform turbidity along the water body.

2.1.2 Secondary data

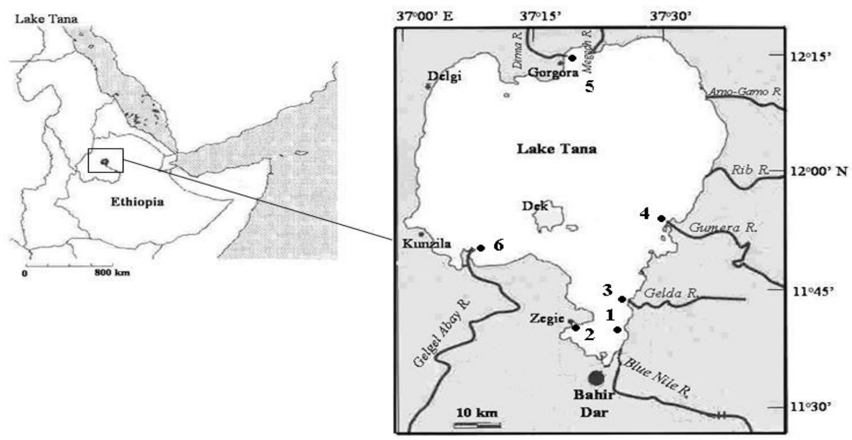
The Bureau of Water Resources in Bahir Dar provided information about water level fluctuations. Climatic data on rainfall, temperature, wind speed and duration of sunshine were provided by the National Meteorological Service Agency as recorded from Gorgora and Bahir Dar stations.

2.1.3 Sampling sites

The six littoral and open water sampling sites for limnological measurements are shown in Figure 2.1. A sample was taken at the littoral (inshore) zone and the pelagic zone at each numbered location on the map.

Figure 2.1 Map of Lake Tana in Northern Ethiopia and the sampling locations within the lake: 1. Gumietirs, 2. Zegie, 3. Gelda, 4. Gumera, 5. Gorgora, and 6. Gilgel Abay.

Comment [CL1]: Zeghe spelling



2.1.4 Measurement of physico-chemical parameters

The physico-chemical parameters were measured from November 2007 to February 2008 between 9.30 am and 1.30 pm at six sampling sites (Figure. 2.1). The pH, water temperature and dissolved oxygen were determined with a combined portable pH/oxygen/temperature meter (YSI model 58). Conductivity was measured using a conductivity meter (WTW LF 56), which was calibrated according to Golterman *et al*. (1978). Light penetration in the water column was determined with a standard Secchi-disk (25 cm in diameter). Major dissolved nutrients (nitrate, phosphate and silicate) from water samples filtered through GF/C, were measured in the laboratory immediately after collection using a portable spectrophotometer (Hach kit, DR/2010). N_2-NO_3, P-PO_4 and SiO_2 were measured by cadmium reduction, orthophosphate amino acid and heterotrophy blue methods, respectively. The depth of the euphotic zone (Z_{eu}) was assumed to be equivalent to the depth at which 1% of the surface light level is detected and was estimated by multiplying the Secchi-disk depth (Z_{sd}) by a factor of 3, which has been frequently employed for productivity estimates in African lakes (Talling & Lemoalle, 1998; Wetzel, 2001).

2.1.5 Phytoplankton and primary production

Phytoplankton was sampled and identification of the species was based on the keys of Horeck & Komarek (1979), as well as from internet-based guides. The results were analyzed and compared with earlier phytoplankton works (Wondie (2006), Wondie & Seyoum (2006), Wondie *et al*.,2007) .

Primary production was measured only at Gelda (site 3) at two stations, one inshore (depth < 3 m) and the other in the open water (depth ca. 10 m). The light-dark bottles technique (Wetzel & Likens, 2000) was used to measure oxygen production at depths of 0.5, 1.2, 1.8, and 2.5 m for three hours during the middle of the day (10.30 and 1.30 hrs). For estimation of chlorophyll-a (chl-a), large (250-1000 ml) volumes of lake water were filtered through Whatman GF/C glass micro-fibre filters. The absorbance of the centrifuged extract was then measured spectrophotometrically before and after acidification (ISO, 1992). Calculations of gross and net photosynthetic rates and respiration rates were based on the changes in the oxygen content in the light and dark bottles and the initial O_2 concentration (Vollenweider, 1974).

2.1.6 Zooplankton and secondary production

Zooplankton was sampled with a plankton net of 64 μm mesh size and 30 cm mouth opening diameter which was hauled along the entire water column (from just above bottom to the surface). Each sample was concentrated to a volume of 150 ml and preserved in 4-5% formaldehyde and sucrose. Identification, enumeration and quantification of zooplankton samples were done using similar methods reported by Wondie (2006) and Wondie & Seyoum (2006).

To estimate secondary production by zooplankton, it was necessary to culture them under laboratory conditions. Food was prepared as mixed algae (natural seston) from lake water, filtered (0.45 μm filter pore sieve) and then cultured in separate culture vessels with Guillard's F/2 inorganic nutrient medium (FAO, 1996). The duration of egg development, naupliar and copepodite instars of copepods, and the neonates of cladocera were measured under semi-natural conditions (22^{o}C) within a 12 hrs photoperiod. These trials were repeated at least ten times and the averages were recorded.

Zooplankton production was calculated using biomass increment method (growth-increment summation model) (Downing and Rigler, 1984, Wetzel and Likens, 2000). The production of the whole population in weight per unit volume and time can be regarded as the sum of the production of the different age classes.

$$\mathbf{P = (N_e \Delta W_e)\, D_e^{-1} + (N_n \Delta W_n)\, D_n^{-1} + (N_c\, \Delta W_c)\, D_c^{-1}}$$ **for copepods**

and

$$\mathbf{P = (N_e \Delta W_e)\, D_e^{-1} + (N_j \Delta W_j)\, D_j^{-1} + (N_a \Delta W_a)\, D_a^{-1}}$$ **for cladocerans**

Where, P is the total production estimate in mg dry weight per cubic meter and day. N_e, N_n, N_j and N_c are the mean population densities of eggs, nauplii, juveniles (neonate) and copepodites, respectively, in numbers per the same unit volume. ΔW_e is the mean weight of an egg (initial weight of nauplii); ΔW_n, ΔW_j and ΔW_c are the mean weight increments of the nauplia, juvenile and copepodite stages from the smallest to the largest, respectively. D_e, D_n, D_j, D_c and D_a are the mean duration of development of the eggs, nauplii, juveniles, copepodites and adults, respectively. In the case of copepods, estimation of naupliar and copepodite production was somatic, while that of the adult was reproductive. D_a was calculated assuming that the rate of increase in body length in adult cladocerans is about three times lower than in juveniles.

Therefore:

$D_a = 3\ D_j * \Delta L_a/\Delta L_j$

Where ΔL_a = length increment from primipara to the average adult

ΔL_j = length increment from neonates to primipara

Production of rotifers in Lake Tana was also calculated using the recruitment method based on the values for the finite birth rate, organism dry weight and egg developmental times (Edmondson and Winberg, 1971). Rotifer dry weight was estimated using an indirect technique of bio-volume calculation from body size measurements and application of an approximate geometric formula (Downing and Rigler, 1984). The production:biomass (P/B) ratio and turnover time $[(P/B)^{-1}]$ were also determined, based on daily and annual averages of biomass.

2.1.7 Energy flow in Lake Tana using Ecopath model

Literature data (Nagelkerke 1997, Wudneh 1998, Dejen 2003, de Graaf, 2003) were used to quantify the parameters of the model. Ecopath modeling software partitions the ecosystem into boxes comprising 'functional groups' with a common physical habitat, similar diet and life history characteristics (Christensen & Pauly, 1992). Many of the functional groups were at species level. For those functional groups which were not previously well-studied, data from literature sources for ecologically similar species were used (e.g. Fishbase, www.fishbase.org).

The functional groups of Lake Tana include the African tilapia, large piscivorous *Labeobarbus* spp*,* large non-piscivore *Labeobarbus,* catfish, *Varicorhinus beso,* small *Barbus, Garra* spp, zoobenthos, herbivore zooplankton, carnivore zooplankton, phytoplankton, and macrophytes. In the present model, fish biomass and production data for the eight fish groups (4 large labeobarbs, *Oreochromis niloticus*, *Claria gariepinus, V. beso* and *Garra* spp.) were obtained from published literature. Besides literature data, some direct estimate values were used for zoobenthos, *Garra* spp., and sessile algae.

The computational methods used to estimate the annual biomass, production, P/B, consumption (Q) of each functional group is described in detail in Wondie (2006). Small barbs form the main biomass of fish in the lake and are the most important link between zooplankton and piscivorous species (Dejen, 2003). Growth, mortality and productivity of the two small barbs of Lake Tana were taken from Dejen (2003). Small *Labeobarbus* is one of the unexploited fish species in Lake Tana and the production estimates were 49 kg ha^{-1} yr^{-1} (16.8 for *B.h* and 32.4 for *B.t*). The annual maximum sustainable yield of *B. tanapelagius* was 3,850 tons (Dejen, 2003).

Comment [CL2]: Labeobarbus or Barbus? B.h and B.t ought to be explained

The average composition of the food of each consumer group was assembled from literature data mentioned above for fish together with personal observations. The diet composition of zooplankton was estimated by analyzing gut contents and by removal methods from field and laboratory samples.

2.2 Results

2.2.1 Physico-chemical features

The data from Table 2.1 was collated and compiled using the results from previous studies (Dejen, 2003; Mohr, 1962; Rzoska, 1976; Wood & Talling, 1988; etc) and provides a good baseline of the chemical parameters. It is important to note that the results of the current study indicate increases in lake turbidity and cation composition, and decreases in nutrients such as nitrates and phosphates. Whether this is due to methodological artifacts or to real changes needs to be ascertained in the future.

Table 2.1. Summary of the Physico-chemical characteristics of Lake Tana

Comment [CL3]: HB to review table and data

Parameter	Mean/range from literature	Results of 2007 study	References
Location	10°58'–12°47'N 36°45'- 38°14'E		Mohr (1962)
Area (km^2)	3,150 – 3,600	3,050 - 3,600	Mohr (1962)
Volume (km^3)	28.4		Mohr (1962)
Max. Length (km)	78		Mohr (1962)
Max. Width (km)	67		Mohr (1962)
Shoreline (km)	385		Mohr (1962)
Max depth (m)	14		Mohr (1962)
Mean depth (m)	8		Mohr (1962)
Renewal time (yr)	6.5 (1.6)		Rzoska (1976)
Catchment area (km^2)	16,500		Gasse (1987)
Rainfall (mm yr^{-1})	1,500		NationalMeteorology (1998)
Temperature (^{o}C)	20-27		Eshete Dejen (2003)
Turbidity (NTU)	20-29		Eshete Dejen (2003)
Conductivity (µS cm^{-1})	115-148	150 - 200	Eshete Dejen (2003)
pH	6.8 - 8.3	6.8 - 8.5	Eshete Dejen (2003)
Dissolved Oxygen (mg l^{-1})	5.9 - 7.3	2.43	Eshete Dejen (2003)
Transparency/Secchi disk (cm)	31-182 (max 300)	100 - 200	Nagelkerke (1997)
Total dissolved solids (mg l^{-1})	148-178		Eshete Dejen (2003)
Na^{+} (mg l^{-1})	7 - 9	1.24 - 55	Rzoska (1976)
Ca^{++}(mg l^{-1})	14 - 15		Rzoska (1976)
Mg^{++} (mg l^{-1})	12 - 17		Rzoska (1976)
NO_3 – N (mg l^{-1})	0.0-0.8	3.3 - 10.2	Rzoska (1976)
PO_4 – P(mg l^{-1})		0.12 - >2	Rzoska (1976)
Chlorophyll a (µg l^{-1})	3.3 - 6.2	2.6 - 8.5	Wood &Talling (1988)

		(mean 4.5)	

2.2.2 Macronutrients

Measurements of macronutrients such as Nitrate-N and Phosphate-P indicated high levels of both nutrients in the surface waters, especially near the southern gulf of the lake. Nitrate values ranged from 3.3 mg/l at the eastern lake shore to a high value of 10.2 mg/l at Ambo *Bahir*, the latter being attributed to the large livestock population. The same trend was observed for phosphate with low values of 0.12 mg/l at the eastern shore and high values of >2 mg/l near point sources of pollution close to the city of Bahir Dar, such as the hospital, prison and the Gilgel Abay river mouth. It is apparent that macronutrients are not limiting for primary producers, and can boost algal production if not limited by light and the high turbidity. In the event of an increase in nutrients, algae including periphytons, can form blooms and macrophyte production that may compete with other organisms for available lake space leading to destabilization of the lake ecosystem. The adapted low-light forms of algae and submerged macrophytes may then dominate the previously dominant algal-forms (Scheffer, 1998) and requires management of the nutrient loading into the lake.

2.2.3 Plankton species composition

There is considerable literature on the biological communities in the lake, which consists of a rich community of algae dominated by diatoms such as *Melosira* spp. and *Syndera* spp. Despite the high turbidity of the lake water, these tiny phytoplankton persist and account for a considerable source of energy transferred to higher trophic levels. The low algal biomass (chl-a) and nutrients noted in Table 2.1 above do not support an abundant planktonic fauna (Bini, 1940). The non-grazing fish comprise only a small percent of the fish catch (Wudneh, 1998).

2.2.4 Phytoplankton species composition and chlorophyll-a

A total of 85 algal species were recorded from Lake Tana (Table 2.2). Chl-a values ranged from 2.6-8.5 mg/m^3 with a mean of 4.8 mg/m^3. The maximum value reported today is slightly higher than the maximum value for chl-a reported (6.2mg/m^3) in Wood & Talling (1988). This increase in Chl-a suggests that there are changes occurring to Lake Tana. The dynamics of the algal species composition requires further studies to reveal changes that may be taking place in response to catchment activities or developments that are occurring around Lake Tana.

Table 2.2. List of phytoplankton recorded in Lake Tana

Family	Species
Cyanophyceae	*Aphanocapsa delicatissima* *Aphanizomenon* sp *Aphanothece clathrata* *A. smithi*

	Chrococcus sp *Cyanodictylon* sp *Limnothrix redekei* *Lyngbya limnetica* *Merismopedia tenuissima* *Microcystis aeruginosa* *M. flos-aquae* *Microcystis* spp *Pseudoanabaena mucicola* *Rhabdoderma lineare* *Spirulina* sp
Chrysophyceae	*Mallomonas* sp
Chlorophyceae	*Ankistrodesmus falcatus* *Ankyra* sp *Chlamydomonas* sp *Chlorella* sp *Closterium aciculare* *Coelastrum microporum* *C. polychordum* *Dictyosphaerium* sp *Diplochloris* sp *Monoraphidium contortum* *M. minutum* *M. tortile* *Pediastrum simplex* *Oocystis parva* *Scenedesmus quadriculata* *S. obliguus* *Schroederia antillarum* *Sphaerocystis* sp *Tetrastrum* sp *Planctonema* sp *Staurastrum triangularis* *S. sebaldii* *Pediastrum boryanum* *P. simplex* *Phacotus* sp *Tetradesmus* sp *Treubaria triappendiculata* *Volvox* sp
Euglenophyceae	*Euglena* sp
Cryptophyceae	*Chroomonas* sp

	Cryptomonas sp *Rhodomonas* sp.
Bacillariophyceae	*Cyclotella comta* *C. meneghiniana* *C. ocellata* *C. operculata* *Cylindrotheca gracilis* *Cymbella affinis* *C. cutula* *C. muelleri* *C. silesiaca* *C. turgida* *Fragilaria brevistriata* *F. virescens* *Gomphonema gracile* *G. lanceolatum* *Melosira (Aulacoseira) agassizi* *M. ambigua* *M. distans* *M. granulata* *M. muzzanensis* *M. varians* *Nitzschia amphibia* *N. filiformis* *N. obtusa* *N. sigma* *Pinnularia major* *Rhizosolenia eriensis* *R. longiseta* *Stephanodiscus hantzschii* *Surirella biseriata* *S. robusta* *Synedra berolinensis* *S. dorsiventralis* *S. ulna* *Tabellaria fenestrata* *T. flocculosa* *Thalassiosira* sp

2.2.5 Primary production

The high turbidity of Lake Tana restricts primary production to a large extent. Chlorophyll biomass is low with a mean of 4.5µg/l. Despite this, some algae adapted to low light conditions (dark adaptation) do well and contribute to some production during the post-rainy season (Oct-Nov), which is also characterized by blooms of floating

Microcystis colonies. The low annual primary production, one of the lowest from several African lakes studied (Wondie *et al*., 2007) implies that algal primary production may not be high enough to sustain herbivores year-round in Lake Tana. The supplementary contribution of macrophyte primary production and the detrital pool derived from this must be important sources of energy in the Lake Tana system (Wondie & Seyoum, 2006). The reduction of the Secchi depth from about 3.0 meters to 1.6m in the last 20 years is a factor that has to be addressed. Reduction in the lake's turbidity would allow a deeper euphotic zone that will increase primary production and the dynamic effects caused by light penetration.

Most of the primary production is by the blue-green algae (Cyanophyceae) and the diatoms (Bacillariophyceae) whilst the contribution of green algae is low and restricted to the dry months of January to March (Figure 2.2).

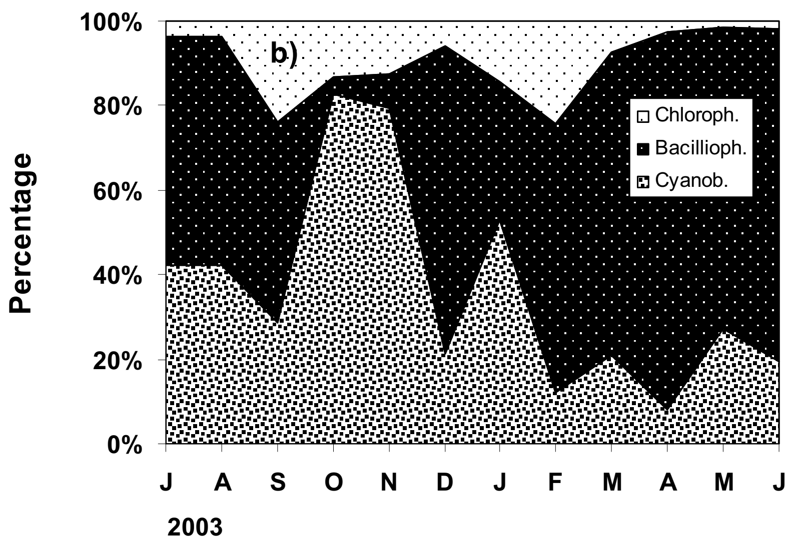


Figure 2.2 Seasonal variation in composition of three main families (Chlorophyceae, Bacilliophyceae and Cyanophyceae) in Lake Tana during 2003/4 (after Wondie, 2006)

The average gross primary production of $2.43gO_2m^{-2}$ was found to be the lowest among 27 African tropical lakes (Ayalew Wondie *et al*., 2007). However, the gross primary production per unit of chlorophyll was in the same range as that of many other African tropical lakes and reservoirs.

The higher primary production in the inshore zone is associated with daily deep-water column mixing which enhances nutrient recycling and, together with the lower turbidity caused by run-offs during the rain season (October to December), promotes blooms of *Microcystis* (Fig. 2.3). Since this colonial blue-green algae is rarely ingested by herbivores, most of it contributes to the detrital pool, also believed to be an important source of energy in the Lake Tana system (Wondie & Seyoum, 2006).

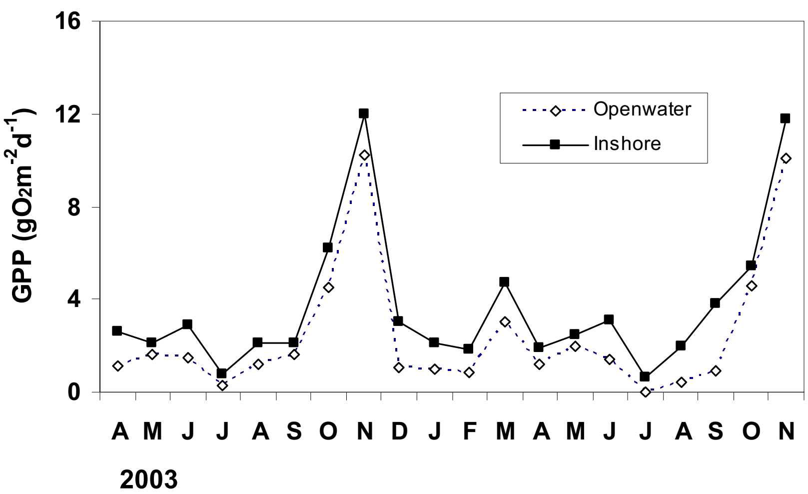


Figure 2.3. Seasonal variation in the rates of gross primary production in the inshore and open water of Lake Tana during 2003/4 (after Ayalew Wondie, 2006)

2.2.6 Zooplankton composition

Brunelli & Cannicci (1940) listed a total of 26 zooplankton species in Lake Tana, consisting of 3 copepoda, 11 cladocera and 12 rotifera. Three recent reports (Wudneh, 1998; Dejen, 2003; Wondie, 2006) listed the major zooplankton in Lake Tana. Wondie & Seyoum (2007) showed that the zooplankton is mainly dominated by the calanoid *Thermodiaptomus galebi*, which contributes more than 50% of the total zooplankton production. Other important members of the zooplankton include the cyclopoids *Mesocyclops* sp. and *Thermocyclops* sp. and 7 cladoceran species - *Diaphanosoma excisum, Bosmina longirostris, Daphnia longispina, D. similis, Ceriodaphnia cornuta,,C. dubia, and Moina* sp. The rotifera in Lake Tana include *Keratella quadrata, Keratella crassa, Brachionus falcatus, Brachionus caudatus, Filinia terminalis, Lecane* sp. and *Trichocera* sp.

The copepods are the most abundant of the three zooplankton groups noted above, whilst the cladocera occur in low abundance (Figure 2.4), probably due to low algal biomass for their grazing, or being out-competed by other efficient grazers, such as calanoid copepods.

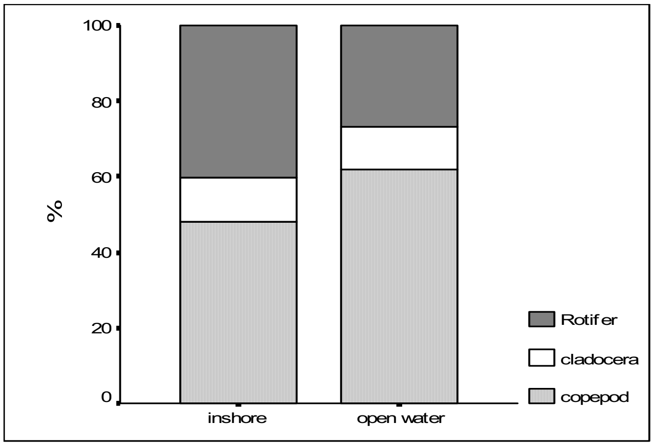


Figure 2.4. The % contribution in mean abundance of the major zooplankton - Copepoda, Cladocera and Rotifera - in Lake Tana during July 2003 - June 2005 (Wondie, 2006)

Comment [CL4]: HB to check reference

Copepods are the highest contributors to zooplankton production in Lake Tana. However, cladocera and rotifers exceed copepod production during the post-rainy season month of August (Figure 2.5). The implications of these seasonal successions in secondary production levels between different zooplankton taxa, as well as their relative abundance have not been adequately investigated.

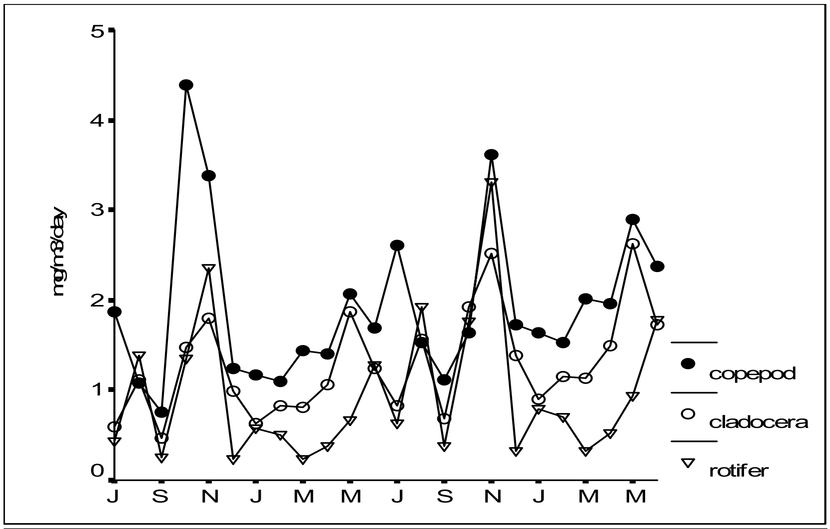


Figure 2.5. Seasonal variation in daily production (mgDW/m^3/day) of Copepoda (•), Cladocera (o) and Rotifera (∇) in Lake Tana during July 2003-June 2005 (Wondie, 2006).

Zooplankton production in Lake Tana is lower than that in Lake Awassa and other African lakes (Seyoum & Fernando, 1991). Cyclopoid production appears to be 10 times lower in Lake Tana than in many tropical lakes. However, the reported annual biomass turnover rate implies that the zooplankton reproduces and replaces itself fairly fast in Lake Tana, possibly due to food availability, especially during the post-rainy season. This fast turnover rate appears adequate to sustain critical, keystone planktivore species, which are important food sources for piscivores in the lake system (Dejen *et al*., 2006).

2.2.7 Macrophytes in Lake Tana

The littoral macrophytes of the eastern and southern part of the lake are listed in section 1.4 of Chapter 1. The river mouths are dominated by papyrus, *Typha* and water lilies. Other macrophytes documented from different areas of Lake Tana include *Echinochloa stagira, Nymphaea coerulea, Polygonum barbatum* and *Pistia stratiotes* (Nile cabbage*)*. Similar occurrences of these macrophytes are reported by Muluneh (2005). Their presence is important to protect the lake from catchment runoff.

The emergent macrophytes such as *Typha* and *Cyperus* provide useful ecological functions, such as refuge sites for fish, aquatic birds, invertebrates and herpetofauna, creating heterogeneous microhabitats that have played an important role in the diversification and speciation of the unique species-flocks of barbs in Lake Tana. Typha and Cyperus also help to stabilize shore structure and reduce the impact of waves and erosion in the littoral zone. These macrophytes have useful economic functions for the local communities as they are harvested extensively and used for religious ceremonies, for building boats and as thatching for local tukuls. Papyrus stands have been extensively removed by direct harvesting and fires (to get rid of wild pigs) in the eastern shores, and from Ambo Bahr and Dengel Mender on the western shores. As a result, the survival of the hippo population is at risk and hippos have been categorized as endangered in large parts of the eastern shores. Near the urban centres, the littoral zone is facing increasing eutrophication and the possible threat of floating macrophyte infestation. Submerged macrophytes are increasing in shallow parts in the southern gulf, and the likelihood of establishment of submerged macrophytes in the less turbid parts of the lake is high, such as near the Zeghe peninsula on the western catchment (Kalff, 2002)

Further studies are recommended on the primary production of macrophytes and periphyton of Lake Tana. The impacts of the seasonal flooding and receding rivers on macrophytes are discussed in Chapter 3.

2.2.8 Food web interactions in Lake Tana

The major ecological components of the food web with regard to fish species in Lake Tana are: African catfish *Clarias gariepinus*, large piscivorous *Labeobarbus* (8 spp.), large benthivorous *Labeobarbus* (5 spp.), large zooplanktivorous *Labeobarbus* (1 sp.), large herbivorous *Labeobarbus* (1 sp.), small barbs, tilapia *Oreochromis niloticus*, *Garra* sp., *Varicorhinus beso*, immature fishes, zooplankton (carnivorous, herbivorous), phytoplankton, sessile algae, macrophytes and detritus. The feeding relationships between the different ecological groups are summarized in Table 2.3.

Table 2.3. Input diet composition (% of weight of stomach contents) of consumers in Lake Tana for ECOPATH model. Estimates for each group is obtained from literature data (Nagelerke, 1997; de Graaf, 2003; Dejen, 2003)

Comment [CL5]: Check title…

Prey																		
Predator		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	*Clarias gariepinus*	0.1	5	3	5	1.5	10	10	0.1	0.1	16	10.2	-	-	9.8	1	-	28.2
2	LLb. piscivores	1.5	-	-	-	-	70.8	1	5	0.1	1.8	-	0.1	1.1	-	-	-	-
3	LLb. benthivores	-	-	-	-	-	7.8	-	-	-	78	-	-	-	13.9	-	0.2	0.1
4	LLb. zooplanktivore	-	-	-	-	-	-	-	-	-	-	24	2	54	10	-	-	10
5	LLb. herbivore	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	75	15
6	Small barbs	-	-	-	-	-	-	-	-	-	-	4.3	8	49.4	19.5	-	-	18.8
7	*Oreochromis niloticus*	-	-	-	-	-	-	-	-	-	-	-	-	-	90	-	5	5
8	*Varicorhinus beso*	-	-	-	-	-	-	-	-	-	-	-	-	-	30	50	-	20
9	*Garra sp*	-	-	-	-	-	-	-	-	-	-	-	-	-	55	30	5	10
10	Immature fish	-	-	-	-	-	-	-	-	-	-	-	-	-	90	-	-	10

11	Zoobenthos	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	24.9	4.9	40	30
12	Carnivorous zooplankton	-	-	-	-	-	-	-	-	-	-	-	-	50	20	-	-	30
13	Herbivorous zooplankton	-	-	-	-	-	-	-	-	-	-	-	-	-	90	-	-	10

The food web relationships and energy flow in the Lake Tana ecosystem were constructed using the Ecopath model. In general, there are two main energy flows where the flow from detritus is as important as the energy flow from phytoplankton. The two main energy flows comprise over 75% of the total energy flow in the system. Chapter 4 deals with this subject in more detail.

The Lake Tana ecosystem possesses more than one major grazing pathway. In general, the following main food chain paths can be taken as examples concerning the fishery of Lake Tana:

Table 2.4 Main food chain paths for fishery of Lake Tana

	Food Chain Path
A	Phytoplankton/Detritus → Herbivorous zooplankton → Carnivorous zooplankton → Small barbs → Large Labeobarb Piscivores
B	Phytoplankton/Detritus → Zooplankton → Zoobenthos → Small barbs → Large Labeobarb Piscivores
C	Phytoplankton/Detritus → Zooplankton → Large Labeobarb zooplanktivore → catfish
D	Detritus → Zoobenthos → Large Labeobarb Benthivore → catfish
E	Macrophyte → Large Labeobarb Herbivore → catfish
F	Phytoplankton → Tilapia → catfish
G	Sessile algae → Garra/*V. beso* → Catfish

Detrital production has not been assessed in detail in Lake Tana, but is believed to be mobilized from macrophyte decomposition through sediments and organic matter input from the inflowing rivers throughout the year. Detritus contains an enormous amount of energy and nutrients. Detritivores (e.g. benthic organisms) obtain their nutrients from the detritus (substrate) in an ecosystem. In Lake Tana, using the Ecopath model, it is shown that phytoplankton are not efficiently utilized by the higher functional groups for the reasons explained above. Therefore, it is likely that detritus from external sources and internal recycling (macrophyte production) may compensate and supplement the food of consumers in Lake Tana. There is a need to study further the dynamics and contribution of organic matter from external sources (inflowing rivers) and from internal macrophytes to the lake ecosystem. A proportion of the energy input into the Lake Tana food web could be through allochthonous sources.

As detritus could play a significant role in the food web of Lake Tana, therefore food chains A, B, C and D could be important pathways. The critical question then is: Which of these are the most important in the Lake Tana food web? The long food chains of A and B are not as efficient as the shorter food chains of C and D. The food chain D is not tenable because benthivorous fish are not very common in the Lake Tana system. Food chain C appears to be the most efficient food chain in Lake Tana and is further discussed in Chapter 4.

For zooplankton to be an efficient conduit of energy transfer in food chain C, it is imperative that they have a fast biomass turnover rate in the system. Studies indicate that P/B ratios of the copepods range from 0.05-0.07 day $^{-1}$, with an annual P/B of 21.4 for the copepod populations. This is not high when compared with annual P/B values of 63.5 for cyclopoids in Lake Chad or 73.5 for cyclopoids in Lake Naivasha, Kenya (Wondie & Seyoum, 2007), but is higher than the mean annual P/B value of 14.5 reported for the cyclopoids in Lake Awassa, Ethiopia (Seyoum, 1989). It is evident then that the copepods in Lake Tana have a high biomass turnover rate, given the turbid nature of the water and food limitation for most of the year (except during the post-rainy season) to sustain planktivores, which are the ultimate food source for piscivores in the system. Alternatively, many fish feed directly on detritus food sources in Lake Tana. The contribution of the microbial loop in energy transfer to zooplankton has not been investigated so far.

The littoral zone occupies a considerable portion of the lake area, but the exact distribution of the different littoral components of the lake have not been delineated, nor the communities that reside therein. In this context, it is not possible to surmise the importance of food chain E. The type of fish feeding on macrophytes is not clear, and thus food chain E may not be that important in a direct way. However, macrophytes, especially submerged macrophytes, are observed to decompose in large parts of the lake shore. This can contribute substantial amounts of detritus to the lake, which accentuates the detrital food chains of A to D, with particular contribution to food chain C. This means that large amounts of macrophyte production and phytoplankton biomass is transformed to detritus and can still be transferred to the higher trophic levels. Other studies on other Ethiopian lakes have shown that detritus is an important food source for a number of fish species (Tefera & Fernando 1989, Tadesse 1999, Bowen, 1980, De Silva *et al*., 1984, Nagelkerke, 1997).

In conclusion, the major contribution of energy to the Lake Tana ecosystem is not the grazer (algal) food web, but the detrital one, with major input from autochthonous sources such as macrophytes and allochthonous sediments and organic matter from inflowing rivers (and other external sources). The Lake Tana food web is sustained from allochthonous sources, very much like rivers and reservoirs. It is no wonder then that some workers liken Lake Tana to a large reservoir fed by several feeder rivers with only one major outflow. The food web picture appears to corroborate this. Lake Tana as a reservoir is a very dynamic lake in which a significant portion of its volume possesses the characteristics and biological functions of a river. Often, the riverine portion of a reservoir operates analogously to large, turbid rivers in which turbulence, sediment instability, high turbidity and reduced light availability preclude extensive photosynthesis, despite high nutrient availability. Because of the large drainage basin of the reservoir, nutrient loading tends to be much higher, although some of the organic matter utilized within the ecosystem originates from internal autochthonous macrophyte sources.

The discussion above indicates that:

- ❖ Lake Tana is a shallow, turbid lake whose limnological functioning depends on continuous mixing (polymictic), nutrient availability and high renewal rates of the water (~ 2 years), phytoplankton and zooplankton;
- ❖ Lake Tana functions like a large river, and its limnology is similarly riverine to some extent given its small drainage ratio, low primary production, high sediment load, riverine barb fishery, detrital and consumer food chains, macrophyte-dominated, persistent turbulence and sediment re-suspension, etc;
- ❖ autochthonous organic matter is a major source of energy (eg from algae, periphyton, macrophytes and to some extent lacustrine fish);
- ❖ the overall low primary production in the lake is supplemented by a high level of seasonal primary production due to intensive wind mixing of nutrients and low turbidity during the post-rainy season: *Microcystis* dominates primary production during this period;
- ❖ Zooplankton production is generally low, but there is adequate nutrition for planktivores (small barbs) and hence for top predators: the small barbs are a keystone species in the Lake Tana food web;
- ❖ Spawning of the large barbs in the river mouths implies adequate food supply for the recruitment of juveniles into the lacustrine zone;
- ❖ Many of the fish species in Lake Tana depend on animal food sources, such as insect larva, fish, mollusks and detritus. The role of detritus and organic silt as sources of energy for the biota needs further investigation;
- ❖ Detritus of autochthonous macrophytes (including periphyton) and allochthonous organic sources are an important component of the energy input into the Lake Tana system;
- ❖ Species diversity, biomass and production rate of macrophytes need to be studied in detail. The possibility of establishment of floating macrophytes and expansion of submerged macrophytes in the less turbid parts of the lake needs to be explored.

The Lake Tana ecosystem can therefore be said to be driven mostly by external energy sources from detrital and sediment input, and supports mainly consumer-driven food chains. The role of primary producers though does not appear to be significant but has cementing relations with the zooplankton. Insect production sustains a diverse community of plantivores and other consumers. The piscivorous large barbs and catfish are at the top of the food chain, which appear dependent more on autochthonous and allochthonous sources of energy, very much like the headwater parts of mesic rivers.

2.2.9 Management issues in Limnology

In order to sustain the unique interrelation of the physical and biological linkages of Lake Tana, it is important to consider maintaining the internal and external energy inputs, and enhancing the functional role of wetlands for nutrient cycling into the lake system.

Particular attention needs to be given to conservation and protection of macrophytes and river mouth habitats, as well as regulation of the high silt and nutrient loading into the lake system.

It is important that specific focus should be given to the following limnological features when developing a management plan for Lake Tana and its associated wetlands:

a) quantification of the amount of sediment load, its retention rate and its accumulation rate in the wetlands, the lake shore, the lake benthos and the out-flowing Blue Nile River;
b) quantification of the nutrients and organic matter retained in the lake;
c) distribution and production of the emergent and submerged macrophytes and the associated periphyton;
d) conserving buffer zones and corridors for plants and aquatic animals between the lake and surrounding wetlands;
e) scientific studies on the role of all ecological components of the lake system, such as benthos, hippos, aquatic birds;
f) adopting a holistic approach rather than treating the lake, wetlands, rivers and uplands in isolation.

2.3. Aspects of water quality in the Lake Tana sub-basin

As noted in section 2.2 above, water quality of the lake and its associated rivers is changing due to catchment-related activities. The main impact may be the effects of water-borne diseases (WHO, UNICEF & UNFPA, 2003) and other serious implications that may affect the whole ecosystem, including changes in the food web as a result of ecological destabilization and loss of valuable species and habitats.

The Bureau of Health (BoH) of the Amhara Regional State has noted that the water quality of Lake Tana is deteriorating due to contamination from wastewater resulting from congested settlement and urbanization in the area. The declining water quality is not only attributed to poor waste management in Bahir Dar town, but also to diffuse inflow from the catchments due to agricultural practices (Yimenu, 2007). As reported in this study, there are evidences of increased concentrations of nitrates, oxygen-demanding wastes, inorganic constituents and microorganisms. In addition, there are physical contaminants that increase turbidity and cause changes in the colour, taste and odour of the water. These are all indicators that the quality of Lake Tana's water is deteriorating.

Wastes generated from governmental and private institutions, including households, commercial enterprises, food and drinking establishments (hotels, bars), health sector institutions, garages, fuel stations and agricultural activities are all critical sources of pollution. So far, no mechanism has been put in place to ensure that polluting institutions bear the cost of pollution. The population in Bahir Dar town and the neighboring locations is also increasing the demand for water consumption. The requirement for water resources from the lake and its tributaries is multifaceted and increasing. However, the threshold of existing water resources to respond to such demands together with any measures that should be taken to ensure sustainability of the resource have not been examined properly.

An assessment of the perception of the respondents to the pollution of Lake Tana water shows that about 20% of the households residing in the adjacent areas observed that the Lake Tana water has become highly polluted while about 11% observed pollution but to a limited degree. However, 17% of the respondents stated that the water is not polluted. Apparently, the majority of the people could not judge the changes in the water quality based on physical characteristics like color, odor or turbidity even in evidently affected areas near to Bahir Dar town.

Water resources in the Lake Tana sub-basin provide various direct benefits to the people, ie as a water supply for humans and livestock, and economic activities through irrigation, fishery and water transport. Its ecological factor is also immense. The town municipality generates income from urban water supply. During 2007, the Bahir Dar town administration generated Birr 7.8 million from water sales. At a daily *per capita* rural water consumption rate of 12 liters and price of Birr 1.75 per m^3, the value of rural water supply in the sub-basin was estimated at Birr 19.6 million per year.

Despite the high price of potable water, the sanitary situation in the sub-basin was observed to be deplorable. Frequent defecation in the open and on the lakeshore was observed. Personal hygiene was poor in almost all households. It is evident that policies that safeguard lake water quality and reduce pollution should be drafted and enforced in the LTSB. Enforcement should start at the urban sanitary facilities and waste disposal systems of Bahir Dar town.

Lake Tana is also used for public transportation where both goods and people are transported. During 2007, public transport generated Birr 3.38 million for Amhara Region while private local water transport service-providers earned Birr 58,000 from the transport of wood and grass. It was also estimated that irrigation water has an added value of Birr 2.5 million in the sub-basin, assuming 2,500 ha of land is irrigated, excluding small scale traditional irrigation. The fishery industry is another economic activity practiced on Lake Tana.

Data on water quality of the Lake Tana sub-basin was compiled from data in different literature using two approaches:

(i) a limited amount of primary data was generated through field sampling of selected sites near the river mouths, at point sources in Bahir Dar city and from some non-point sources.
(ii) secondary data was accessed by visiting libraries and archives of relevant stakeholder institutions, individuals, universities and government ministries,

Comment [CL6]: need references and dates

2.3.1 Water Quality Results

Water Chemistry
The data compiled from the sources in (i) and (ii) above are presented in Tables 2.5 and 2.6.

Table 2.5 Chemical composition of Lake Tana river mouths and Bahir Dar area (primary data)

Chemical Parameters	Zeghe Giorgis	Ambo Bahir	Gilgel Abay pelagial	G.A. river mouth	Egashu R mouth	Prison	Tana Hotel	Hosp.effluent
Depth (m)	9.3	0.6	9.7	2.5	0.60	1.05	2.30	-
pH	6.88	6.98	7.02	-	7.33	6.57	ND	7.27
Turbidity as NTU	21.99	81	3.42	55	12.19	0.00	11.73	0.00
Copper as Cu, mg/l	0.021	0.0091	<0.001	0.0249	<0.001	<0.001	<0.001	0.01
Lead as Pb, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.0007	<0.001	<0.001
Zinc as Zn, mg/l	0.0289	0.0254	<0.001	0.0072	<0.001	0.0056	<0.001	0.015
Chromium as Cr, mg/l	<0.001	0.0263	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium as Ca, mg/l	2.45	9.29	10.5	3.11	ND	ND	ND	ND
Magnesium as Mg, mg/l	0.47	1.84	2.21	0.56	4.18	ND	ND	4.49
Ammonia as N, mg/l	0.2	0.2	0.11	0.25	0.21	0	0	0.45
Nitrate as N, mg/l	6.7	10.2	5.2	5.9	3.3	7.1	4.9	6.6
Phosphate as PO_4, mg/l	1.03	1.03	2.00	0.69	0.12	2.01	1.96	2.13
Iron as Fe, mg/l	0.001	0.0077	0.017	0.024	0.0932	0.0583	0.181	0.187
Potassium as K, mg/l	0.40	1.79	ND	0.56	3.00	ND	ND	ND

Table 2.6 Chemical composition of upper Lake Tana catchment sites (secondary data)

Chemical Parameters	Woreta	Aykel	Debre Tabor	Nefas Mewcha	Chagni	Bure	Dejen
pH	7.5	7.0	8.0	8.5	6.95	6.8	8.06
Color as Pt-Co units	11	113	-	-	79	5	-
Turbidity as FTV	3	21	2	1	12	8	-
Conductivity, ms/cm	0.47	0.09	0.20	0.26	0.27	4.26	0.39
Total Alkalinity, $CaCO_3$,mg/l	240	40	150	110	70	2920	200
Carbonate Alkalinity, $CaCO_3$, mg/l	80	40	100	140	80	2800	200
Total Hardness, $CaCO_3$, mg/l	80	40	100	140	80	2800	200
Calcium as Ca, mg/l	28	16	20	28	1	200	49
Magnesium as Mg, mg/l	2.4	2.4	11.9	16.8	1.24	551	19.5
Manganese as Mn, mg/l	-	0.05	0.01	0.02	-	0.02	-
Copper as Cu, mg/l	0.01	0.27	0.04	0.12	0.16	0.152	0.02
Nitrate as N, mg/l	1.18	4.20	3.6	3.7	19.36	31.6	5.72
Phosphate as PO_4, mg/l	0.44	0.23	0.34	1.07	0.42	2.39	0.96
Fluoride as F, mg/l	0.21	0.53	0.57	0.33	0.15	0.22	0.50
Chloride as Cl, mg/l	10	5	5	5	10	15	10
Iron as Fe, mg/l	0.16	0.41	0.02	0.01	0.10	0.30	0.01

From the tables above, the water chemistry at the river mouths of Lake Tana indicate low, and often undetectable, concentrations of heavy metals. This is to be expected, as there are few industrial activities in the area at the moment. However, the nutrient levels were quite high. For example, in all sites sampled, phosphate levels were above the lower limit of 100μg/l at which point eutrophication occurs in water. The high nutrient levels are due to fertilizer use by farmers and the long-term accumulation of nutrients in the lake due to its high nutrient retention efficiency.

Generally, water turbidity and conductivity were low in upper catchment sites (Table 2.6) except at Aykel. The slightly higher turbidity level at Aykel could be the result of extensive soil erosion which, it is suspected, originates from upstream sources such as the Choke mountain ranges. The low values in other sites could be the result of samples being taken from close to town and city areas where people fetch relatively cleaner river and stream water for potable uses.

The town of Bure is relatively urbanized and populated and water samples showed higher alkalinity and total hardness, as well as high levels of calcium, magnesium and nutrients. The moderate level of agro-industrial activity in this town may be responsible for this; however, the unusually high values could also be due to methodological artefacts which have to be authenticated again. The water samples from Dejen town on the southern catchment gave high levels of nitrate and fluoride. There may exist point sources of mobilization of macronutrients and chemicals from a few upper catchment sites, such as Bure and Dejen towns into the Lake Tana sub-basin.

Nutrients

River mouths had higher nitrate and ammonia concentrations than the seemingly polluted sites near Bahir Dar. This could be due to the presence of livestock and water birds and the accumulation of their wastes in these areas. On the other hand, phosphate levels were at similar concentrations at both the river mouths and around Bahir Dar, suggesting comparable pollution and influx of nutrients from urban discharges and animal wastes, as also observed by Adane (2006) and discussed in Chapter 5 on invertebrates.

The upper catchment of the LTSB had lower phosphate levels, except Bure town, which may reflect the high degree of urbanization of this town, and lower nitrate values than in the lake catchment, indicating some degree of mobilization of these nutrients from the rivers or urban sources. However, in areas such as Aykel, Dejen and Chagni, nitrate levels were higher, which could be due to livestock and domestic wastes, or other local factors, including destruction of wetlands. A nitrate concentration above 10mg/l not only contributes to eutrophication, but can cause blood disorders in infants (blue baby disease): previously, this was recorded only from Chagni in the upper catchment. Elevated nitrate levels indicate that manure, sewage, or nitrogen fertilizers are reaching the water source, with no chance of being modified through wetlands.

Bacteriological

Samples for bacteriological analyses were collected on-site by technical staff of the WRDB of the Amhara State. Surface samples were filtered through membrane filters and incubated in Lauryl Tryptose broth with MUG. Incubation was within 3 hours of collection. Colony growth of *E.coli* was observed after 24 hours of incubation and the presence of fecal *E. Coli* expressed as cfu/100ml broth media. Results of the analysis are presented in Table 2.7.

Table 2.7 Bacteriological results of Lake Tana river mouths

Bacteriological Parameters	Egashu River mouth	Prison	Tana Hotel	Hospital effluent
Membrane filtration and Lauryl Tryptose Broth with MUG *E. Coli* cfu/100 ml	10	30	10	20

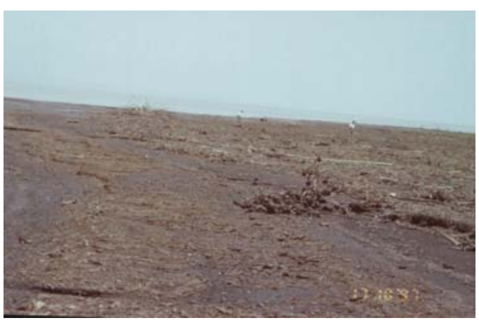
Coliform bacteria analysis detects both non-pathogenic and pathogenic bacteria. Since the identification of specific pathogenic micro-organisms is difficult, total coliform is often used as an indicator of the presence of disease-producing organisms that normally live in the intestinal tracts of man and warm-blooded animals. The density of total coliforms does not necessarily relate directly to the population of pathogens, but provides an estimate of the extent to which the water has been contaminated by human wastes. Specific disease-producing organisms are difficult to identify in water. Therefore, while total coliform and aerobic/anaerobic bacteria are themselves not harmful, their presence signals that bacterial contamination from either human or animal fecal sources may have occurred.

The lake and river water in the LTSB is highly loaded with suspended solids, which is an indication of land degradation. The presence of *E. Coli* at the sample sites is an indication of fecal contamination of the surface waters at the river mouth area and at the urban shores. Since fecal coliforms are regarded as more accurate indicators of fecal pollution, their presence in treated water is taken as a sure sign of high health risk. No fecal coliforms should, therefore, be found in 100ml of water samples. Public awareness by health authorities is important to inform citizens of the hazards associated with living alongside a polluted lake. Environmental water and sanitation programs need to be implemented in the sub-basin.

Regular monitoring of point and non-point source pollution should be done near the lake shore and river mouths. The WHO 'Guidelines for drinking water quality' (WHO, 1993) should be consulted. It is recommended that the regional water laboratories should be strengthened with qualified personnel, appropriate equipment and the necessary logistics. In addition, water quality laboratories should be established at Wereda[1] level to monitor the status of water resources in the Lake Tana sub-basin on a regular basis.

2.4 Aspects of Wetlands of LTSB

[1] Lowest administrative level with a health center

Bird habituation and human encroachment 	Pristine wetland at Derima (bio-reserve) 
Blue Nile Riverine wetland 	**Wetland trapping sediment into Lake Tana** 
Alluvial sediment deposit at Gilgel Abay River mouth 	**Silted wetland of the Blue Nile outlets** 

During this study, representative points were sampled and stakeholders were interviewed using rapid assessment methods developed for wetlands and rivers (Barbour *et al*., 1999). The macrophyte zones of papyrus and Typha stands were approached by boat and from selected terrestrial points. Interviews focused mainly on stakeholders living around and within the lake, and sampling focused on representative habitats and dominant species. These limitations have to be under-scored when the biodiversity and habitat quality of the sub-basin is described within the present context.

The locations of the wetlands considered for this study are shown in Figure 2.6 below.

Comment [CL7]: insert locations

Figure 2.6. Lake Tana and its major wetlands

With the exception of coastal and marine-related wetlands and extensive swamp-forest complexes, all forms of wetlands are represented in Ethiopia (Abebe, 2003). These wetland resources include lakes, marshes, and swamps, located in various parts of the country from lowlands to highlands. However, their area coverage has not yet been determined.

Wetlands in Ethiopia have different socio-economic values. These include food crops supply through agriculture by draining and recession, important sites for dry season grazing, resource extraction, raw materials (reeds for thatching purposes, papyrus), fish harvesting, medicinal plants and sites for tourist attraction and various traditional ceremonies. They are also part of the rural people's economy as they traditionally play an important role for rural communities through the provision of water and other materials for both humans and livestock. Studies indicate that some wetlands like Tana, Fogera, Chefa, and the Rift Valley wetlands are the resting and nesting areas for inter-Africa and European migratory birds and add to their tourist attraction.

Types of wetlands in Lake Tana sub-basin

For this report, the wetlands occurring in the LTSB have been classified into the following four major ecosystems or habitats using the system adopted by Omoding *et al*., (1996) for Ugandan wetlands:

i) Riverine wetlands
ii) Lacustrine wetlands
iii) Palustrine wetlands
iv) Agricultural floodplain wetlands.

(i) Riverine wetlands

These include all permanent and seasonal rivers and streams together with their associated inland deltas and flood plains. EPLAUA (2005) indicates that there are over 61 permanent and seasonal rivers and streams feeding into Lake Tana. All of these rivers and streams discharge their waters into the lake through different geomorphic processes, such as bank erosion, sedimentation, channel movements, undulating and meandering river courses and oxbows. Frequently, this leads to seasonal over-flooding with a high influx of alluvial soils blended with nutrients at their lower reaches resulting in the creation of various marshy and swampy habitats and biotic communities.

Comment [CL8]: expand the acronym

All these permanent and seasonal feeder rivers and streams are ecologically significant in that they provide habitats for breeding and spawning grounds of riverine migrating fish species, especially for the endemic fish stock. Accordingly, they play keystone ecosystem functions. The dynamic nature of riverine wetland ecosystems, which are usually perturbed and constantly changing, results in a spatial and temporal structuring of the wetland. Such a dynamic process is frequently created by massive sediment accumulations along the meandering bends of the rivers and streams at their lower reaches thereby creating new channels that take short-cuts between bends leaving the original bends abandoned. As a result, new and diverse mosaic wetland habitats are created in time and place. Of the riverine wetlands, the banks of the Gilgel Abay, Gumara, Rib and Megech Rivers (see Figure 2.1) are frequently perturbed for agriculture. The resultant sedimentation of such riverine wetlands into Lake Tana has not been studied, although silt loading of the Gilgel Abay River as it streams into the lake continues to be observed, suggesting that river banks need to be protected to prevent sedimentation of the Abay River as it leaves Lake Tana and heads to the Tis Issat waterfall.

The Upper Blue Nile River basin system acts as a green corridor in linking the catchment with the lake system as well as a buffer against the exchange of materials to and from the lake. It has patches of intact forests and riparian *Cyperus* papyrus vegetation, which act as buffer strips along its watercourse (30kms in length) and provide habitats for waterfowls, terrestrial birds and some mammals.

(ii)Lacustrine wetlands

This category of wetland includes the entire shoreline surrounding Lake Tana. Based on the Ramsar Convention's definition of wetlands (Article 2.1), the lacustrine wetland of

Lake Tana, with an area of 3,200 km^2 and an average depth of less than 6 meters, qualifies as an inland freshwater wetland. The lake is divided into littoral, sub-littoral and pelagic zones, based on light penetration conditions and macrophyte concentrations. All of these zones are interlinked and provide habitats for the various fish stocks and other aquatic life forms. The degree of perturbations of the zones, and their dynamic changes due to sedimentation processes remains to be clarified.

The lake is an important evolutionary laboratory. The hypothesis is that *Barbus* fish flocks in Lake Tana stemmed from an ancestral riverine benthivorous barbus species reminiscent to *B. intermedius*, which is commonly found in the highlands of Ethiopia (Sibbing *et al*., 1998, cited in de Graaf, 2003). The subsequent evolution of this species flock provides a natural laboratory for empirical scientific evolutionary research on the selective forces driving speciation and diversity in freshwater communities, as well as providing a model experimental laboratory to replicate effective conservation of the world's freshwater ecosystems.

Comment [CL9]: flock? Stock?

The destruction of lacustrine wetlands has impacted on fish stocks. Overfishing and the use of poisons in spawning grounds have affected recruitment, particularly specialized lacustrine fish stocks that have narrow habitats as compared to the 'generalist fish stocks' with wider habitats.

(iii) Palustrine wetlands

These comprise the emergent vegetation and forested shrub, scrub and thickets that are either permanently or seasonally flooded marshes and swamps growing on inorganic soils. The various palustrine wetland ecosystems, located on-shore and off-shore, are valuable ecological units that conserve important genetic resources and biodiversity species. The various vegetated wetlands have important ecological linkages between the water realms of the lake and terrestrial lands and hence play keystone ecosystem functions in reducing point and non-point source pollutions, regulating flood velocity, providing important habitats for waterfowls and breeding and spawning grounds for fish species. Because of the presence of water, these wetlands are ecologically significant in conserving the water tolerant vegetation communities of *Cyperus papyrus* and *Typha latifolia*.

(iv) Agricultural floodplain wetlands

This comprises mainly the Fogera floodplain wetlands (see Figure 2.1), located within latitude 11°44'-12°03'N and longitude 37°25'-37°58'E. These seasonal floodplains are located in the eastern side of Lake Tana and have an estimated area of 28,000 hectares. These wetlands are thought to have been part of the lake, but, due to long-term pluvial periods, have changed into the present land forms because of high sediment loads from inflowing rivers to Lake Tana. The soils are alluvial with no stones. Because of their fertility they have been used for agriculture for several thousands of years. The most important river that overflows its banks to make seasonal wetlands is the Rib River which eventually flows into Lake Tana. The habitat structures of the flooded wetlands include both semi-natural and arable lands, which are critically important in agro-biodiversity, rice cultivation and a unique cattle breed known locally as "Fogera" breed. Similarly, these floodplains maintain several varieties of cereal crops and oil seeds including *Guzotia abyssinica* and *G. scabra*.. It is important to manage the silt deposited in these areas as both the silt and the floodplains are used for agriculture.

Uses and functions of wetlands in the LTSB

The existing resource uses of Lake Tana and its associated wetlands can be broadly divided into consumptive and non-consumptive uses, as indicated in Table 2.7 below.

Table 2.7 Summary of direct and indirect benefits of resource utilization in Lake Tana wetlands

Uses of direct value

- Commercial and subsistence fisheries
- Recession agriculture and cultivation lands
- Communal grazing
- Water supply for drinking
- Hydropower generation
- Reed harvesting
- Small and large scale irrigation
- Fuel wood and construction materials
- Sand mining
- Navigation and traditional boating
- Cultural museum
- Waste dumping
- Urbanization and infrastructure development
- Investment
- Settlements
- Religious place
- Temperate wintering
- Horticulture and plantation

Indirect benefits

- Natural research area
- Aesthetic value
- Eco-cultural tourism
- Relaxation and recreation
- *In-situ* conservation and preservation
- Environmental and educational value
- Scientific research and monitoring
- Historic and cultural value
- Spiritual value

The functional evaluation of the wetlands was based on the judgment of the researcher, who scored the wetlands against its given function depending on the common uses in the area. The scores are presented in Table 2.8.

Table 2.8 Results of wetland functional evaluation analysis

No.	Function	Zeghe	BD Zuria	Delgi-Takusa	Fogera	River side	Gilgel Abay
1	Water storage for flood control and storm runoff Not significant if less that 1% of watershed or contiguous to a major lake and scoured banks Significant if has woody vegetation	8	4	9	0	2	2

2	Surface and ground water protection Significant if recharges groundwater, constricted or no outlet, hydroperiod permanently flooded, sediment removal or retention, in depositional environment, peninsula	3	5	7	2	7	3
3	Erosion control by binding and stabilizing the soil Significant if forested or shrub wetland, vegetation > 20ft, substrate is rough, interspersed vegetation	6	4	7	1	2	1
4	Fisheries habitat Significant if spawning ground contains overhanging vegetation that provides shade, insect food, etc	6	4	9	4	8	6
5	Wildlife and migratory birds habitat for feeding, breeding, roosting, nest site Significant if emergent vegetation occupies 26-75% of wetland area, contiguous to lake or stream	4	2	8	5	7	4
6	Hydrophytic vegetation habitat rushes, cattails, shrub swamp, disjunct plant species 40 miles from nearest population	8	6	9	2	8	3
7	Threatened and endangered species habitat If area has reported presence of such species in the past 10 years based on IUCN categories	8	3	8	2	7	5
8	Education and research in Natural Sciences Owned by public entity and used for education or research	8	7	8	2	8	7
9	Recreational and economic values fishing, hunting, reed harvesting, wild foods	8	4	8	3	8	8
10	Aesthetics/open spaces public exhibition, unique aesthetics and landscapes	10	2	9	3	8	7
	TOTAL %	**69**	**41**	**82**	**24**	**65**	**46**

Interpretation: 90-100% Excellent, pristine, full ecological functions retained
80-90% Still provides good functions
75-80% Fair functions

50-75 % Poor ecological functions, impaired

The above table shows that the ecological functions of most wetlands in the Lake Tana sub-basin have been highly compromised e.g. The Bahir Dar Zuria wetlands have lost their aesthetic, educational, research and economic qualities due to pollution while they have retained some functions such as habitat for fisheries and hydrophytic plants. These wetlands have little role in protection in reducing catchment impacts and because of their alteration they develop a new function as habitats for pathogens and water-borne diseases. Common flooding hazards in the city of Bahir Dar attest to the fact that these wetlands may not afford much protection against floods and storm water runoff. It is for this reason that the city administration has constructed five major canals to collect storm water and runoff from the city and drain it into the lake. It is not uncommon to observe people connecting their sewage waste into the canal system, thereby exacerbating organic pollution at several point sources into Lake Tana.

The ecological functions of the Gilgel Abay wetland are important in terms of their role in the control of floods, erosion and groundwater protection. It is a habitat for hydrophytic plants, fish and some migratory birds. It has some aesthetic qualities and may have an educational value as it serves as a good demonstration of sedimentation loading of rivers.

The Fogera floodplain wetlands have the least score for functional evaluation (24%) implying that the essential functions of these wetlands has been reduced (as a result of silt deposits and fill-up). Thus, instead of controlling flooding hazards, these wetlands enhance flooding and it is not uncommon to witness some years when the farmers are dislocated and have to abandon their surrounding fields and homes. Although the biodiversity of this wetlands habitat (such as birds, fishes, hydrophytic plants and other wildlife species) is very rare, the wetland can be restored as a floodplain to control erosion and floods. Accordingly, their transformation into floodplain agricultural lands requires good management and technical capacity.

The city authorities of Bahir Dar have proposed the riverside wetlands of Zeghe Gerima (69%) and Riverside (65%) to be designated as parks. Both wetlands perform useful functions such as flood and erosion control, and act as habitats for fish, hydrophytic plants, wildlife and birds. They also have good aesthetic and recreational values. if properly developed.

Takusa wetland, with the highest functional evaluation (82%) provides useful ecological functions, such as flood and erosion control in the north-western parts of Lake Tana. It is also habitat to important water fowl, which are seen in large numbers feeding and roosting in these wetlands. This wetland is an important habitat for hydrophytic plants and it has high aesthetic and educational value. Although not currently used for recreational purposes, its potential to be used for this purpose is high due to the presence of diverse pristine habitats. Some of the birds seen in this wetland migrate from as far as the Alitash wetlands near the Sudan border and the Kunzila wetlands around the western shores of Lake Tana.

It can be concluded that most wetlands around the Lake Tana sub-basin have been impacted upon. The existing wetlands require a good management regime so that they continue to function as habitats for biodiversity such as fish, birds, hydrophytic plants, which need urgent protection and conservation measures as they continue to provide their ecological functions in the future. Some wetlands have been transformed into agricultural lands and these should be managed so that they do not lose their ecological functions to provide food and continue to serve as corridor refugia for biodiversity.

Major threats to wetlands

The wetland ecosystems of Lake Tana have been disturbed by anthropogenic and natural impacts causing extinctions/extirpations and decreasing diversity. The dynamic regimes of flooding and inundation of the rivers and the lake is driven by basin precipitation and overflows, and inundates from rivers and the lake itself. The timing, depth and duration of seasonal flooding need to be monitored as a regulating factor to human disturbance that may be detrimental to the distribution of wetland vegetation.

Vegetation structure, composition, diversity and richness have been driven mainly by tolerance to flooding over the years. If wetlands were absent, the impact of the drought years of the 1970s and 1980s on renewable resources would have been more severe. The wetlands and their vegetation are the main storage of the water and regulate the flow in the Abay River even in the periods of long droughts.

The vegetation communities/associations are adapted to heavily water-saturated soils and anaerobic conditions with low oxygen compensation thresholds, a characteristic that allows tolerance/survival under heavily saturated soils. The vegetation is adapted to changes in flood frequency, flood depth and flood duration. The drainage to swamps affects the vegetation structures, composition, diversity and richness leading to habitat loss and fragmentation and species extirpation. The 40 years of intensive agriculture in the sub-basin could have caused the demise of the once widespread swamp and marsh wetland vegetation communities, associations and populations in the vast associated wetlands of Lake Tana and its associated rivers. The destruction of the once widely distributed water-tolerant papyrus-typha communities is connected with habitat fragmentation and loss as a result of dynamic human utilization of the wetlands over time.

Impacts on wetlands

Deforestation and overgrazing have contributed to erosion of wetlands in Ethiopia and, as a result, sedimentation of the water bodies is threatening the role of wetlands as important habitats for birds and other wild animals. Increased accumulation and sedimentation will ultimately accelerate the ontogeny of the wetland, i.e., the rate of conversion of the aquatic system to a terrestrial one (Wetzel, 2001).

The major cumulative impacts on wetlands have resulted from agricultural practices in the uplands and in the wetlands themselves. Cumulative adverse impacts to wetlands might reduce their capacity to mitigate flooding and loading of suspended solids.

Although the socio-economic values of wetlands are appreciated, little is understood about the biological diversity and richness of wetland resources in Ethiopia. This is typically reflected in the Lake Tana wetlands where research has not yet been conducted. Although wetlands in Ethiopia have been drained and used for food production for decades the extent of wetland dynamics in the Lake Tana sub-basin has not been determined. Research on environmental, biological and socio-economical aspects of these wetlands is crucial to address some of the gaps in wetland assessment and some of the problems associated with Ethiopian wetlands.

Increases in temperature and rates of evaporation caused by climate change may also result in a loss of wetlands. Hussein (2006) showed that climate change could influence the hydrology of Lake Tana sub-basin by affecting the magnitude and seasonality of surface flows.

Current condition of LTSB wetland
A rapid assessment of LTSB wetlands was carried out on the current on-site trends in biological diversity. The main wetlands assessed included:

1. Zeghe wetland at Gerima
2. Bahir Dar Zuria wetlands
3. Delgi-Takusa wetlands
4. Fogera floodplain wetlands
5. Riverside wetlands
6. Gilgel Abay floodplain wetlands

The results of the scoring and condition index for the six wetlands covered in this study are presented in Table 2.9 below. This index is calculated from the mean of hydro-geomorphic condition, vegetation condition, water quality, buffer condition and restorability, and is interpreted as follows:

> 0.9 - 1.0 = Excellent
> 0.7 - 0.9 = Good condition
> 0.5 - 0.7 = Fair condition
< 0.5 = Poor condition

Comment [CL10]: check numbering

Table 2.9 Scoring and Condition Index for six wetlands of the LTSB

Wetland	**Zeghe at Gerima**	**Bahir Dar Zuria**	**Delgi Takusa**	**Fogera flood plains**	**River side wetlands**	**Gilgel Abay**
Type	Palustrine –	Palustrine –	Palustrine –	Floodplain	Riverine	Floodplain

	lacustrine	lacustrine	lacustrine	Cropland		
Flooding	Permanently flooded	Permanently flooded	Permanently flooded	Seasonally flooded	Permanently flooded	Permanently flooded
Biota Emergent vegetation of *Cyperus* and *Typha* Fish present Amphibians Birds	+++ ++ + ++	++ + + ++	++ + + +++	- - - +	+ ++ + ++	++ ++ + +++
Condition index	0.82	0.66	0.81	0.60	0.73	0.71
% of standing water	100	100	100	5	100	100
Status	Good	Fair	Good	Fair	Good	Good

+ indicates the relative abundance of the biota
- indicates no biota seen

Wetlands such as those at Bahir Dar Zuria are in the fair category. The Fogera wetland plains have been impacted upon by urbanization pressures and long-term sedimentation. Additionally, they are under threat of transformation into agricultural rice fields and crop lands. Zeghe Gerima wetland is the least impacted (it has been proposed as a biosphere reserve) together with Takusa wetland - they are pristine wetlands in the western shore of Lake Tana and are categorized as ‘excellent’, although some intervention is required to ensure they continue to offer their services.

In general, the assessment of wetlands in the Lake Tana sub-basin shows that:

- a few wetlands in the Lake Tana sub-basin still exist and can be used wisely. These include the Gerima wetlands near the Zeghe peninsula and the Takusa wetlands further west.
- other wetlands, such as Fogera and Dembia, have been severely degraded due to drainage for agriculture use, sediment fill-up due to inundating rivers, rice cultivation, sand extraction, unwise reed harvesting, unplanned settlement schemes, organic pollution and waste disposal, hydrological alterations, and water quality deterioration. Accordingly, they require serious conservation measures.
- wetlands close to major urban centers such as Bahir Dar have been subjected to increasing pressures but could be turned into wise-use ventures to promote their conservation. Unplanned investment activities such as dredging or filling up some wetlands will have serious impacts.

- In areas where wetlands have been transformed to agricultural lands, the biodiversity has likewise been transformed from wetland species to cropland species. This is clearly observed in the monoculture vegetation of crops, eucalyptus trees and rice in the Fogera and Dembia floodplain wetlands, and in the remnants of flood/water tolerant or intolerant plants in other wetlands. Overall, biodiversity has changed and these changes have to be closely monitored in the Lake Tana wetlands.
- Despite human pressure and wetland transformations, bird, amphibian and insect diversity in wetlands remains high. This is partly due to the survival of remnant wetland habitats which act as refugia for these species, and to the islands in the lake, which have preserved many of their original features on account of human emigrations.

- The monks in the monasteries found on the islands have guarded the wetlands and their plant and animal biodiversity to a large extent, as is the case in areas where the monasteries are found outside the lake.

The hydrological contribution of the sub-basin wetlands to Lake Tana has not been assessed in detail. However two scenarios can be envisaged:

(i) During the *rainy months* of July-September, the wetlands fill and the excess sediment is carried into Lake Tana. This implies there are not enough wetlands to deal with the silt problem from the catchment where activities have not been monitored to reduce sediment run-off. It is likely that the sediment accumulated overwhelms and may alter the spawning ground of fish. The silt that enters the lake is visible at the river mouths and lake shores and is a serious issue that threatens sedimentation in the lake.

(ii) During the *dry months*, the wetlands which stored the water act as discharge points to the lake and rivers. They maintain the biodiversity which would have migrated during the dry months and permit a continued agriculture occupation during the dry season.

The wetlands are therefore threatened at several levels: the silting up of the wetlands because of the increased erosion from the catchments and the expansion of agriculture and increased grazing pressure targeting wetlands. However, some activities alter the nature of the wetlands by filling in sections of wetlands with soil to increase the area suitable for crop cultivation or to carry out construction. In all cases, a good management practice can set guidelines to control and use the wetlands wisely and avoid hydrological consequences that could influence the groundwater level or cause salinisation, although the extent of this problem in the Lake Tana sub-basin has not been studied extensively.

2.5 General conclusion on LTSB wetlands

Despite the significant human impacts, the LTSB wetlands remain important areas containing biodiversity. Their conservation needs should be given due consideration by the Government and the local communities. The existing biodiversity demonstrates advanced adaptive mechanisms and provides outstanding potential for recreational, scientific, aesthetic, educational and tourism-related activities.

The relentless pressure on wetlands comes from rapid urbanization, some industrialization, agricultural intensification, massive land use changes and a high human population growth rate.

The last remnant patches of the once extensive ever-green forests found within and around the churches and monasteries should be conserved. These relict forest lands have long been inviolate as sacrosanct forests, guarded jealously against iconoclasts, but today they are threatened with endangerment stemming from underlying socio-economic factors and cultural decadence. Rapid intervention is needed to arrest the likely trends of further deterioration through strengthening traditional institutions and organizations, and improving their awareness of resource utilization and management.

The LTSB wetlands are widespread and subject to diverse public uses, making their conservation complex. Creating a series of interconnected habitat reserves that include zones with varying types and intensities of human uses could provide a solution to resource abuse as well as facilitate functional interconnection.

The mosaic ecosystems and habitats of the associated wetlands of Lake Tana provide a refuge for temperate wintering of Palearctic and Eurasian birds during adverse conditions. Indeed, they are critical habitats for globally threatened bird species, biome-restricted assemblages and congregations of as many as 20,000 waterfowl. This is manifested by the designation of Lake Tana and Fogera Flooded Plains as globally Important Bird Areas (IBAs). Thus, Lake Tana and its associated floodplains deserve due attention for conservation on a sustainable basis.

Management responsibilities of the lake's water resources are vested with different stakeholders, ranging from federal to local and thus require different management options to provide opportunities for decision-making processes and the development of a common framework for sustainable management. Naturally, most stakeholders are inward-looking, focusing on meeting their own interests without regard to other users. For this reason, alternative management options need to be developed that consider their respective management objectives including sustainable utilization of renewable resources.

2.6 Conservation priorities in the LTSB

Water level fluctuations have considerable impacts on macrophytes (Wallsten & Forsgren, 1989), although other biodiversity such as amphibians, birds, fish, invertebrates and even aquatic mammals could also be affected. Conservation efforts in lake ectones should consider buffer zones and corridors for the protection and passage of endangered animals and plants. Terrestrial uplands need to be protected against excessive soil erosion and cover-stripping. Appropriate land use policies and methods need to be adopted by national and local governments as well as by the relevant communities. The role of

NGOs and religious institutions should be streamlined and exploited for such noble purposes.

2.6.1 Conservation of Fogera floodplain wetlands

The Fogera floodplain wetlands provide habitats for wildlife species, particularly waterfowl and seasonal migrating fish stocks for spawning. The ecological significance of this area is manifested by its international recognition as an IBA, as it supports some globally threatened species of birds. Despite this, the Fogera floodplains are threatened with ecological degradation stemming from drainage and channeling, invasion by alien species, and the expansion of monoculture cultivation. Management intervention is needed if the Fogera floodplain wetland is to achieve sustainable development.

The Fogera floodplain wetlands have been, and are being, used as demonstration models for rice production in the region and the country as a whole. In the 1990s, the Bureau of Agriculture reintroduced two rice varieties (*Oryza* spp) locally called "X-Gegna/White Rice and IIC-164/red rice". The former variety has thrived very well and thus received social acceptance by farming communities. As a result, expansion of rice cultivation has increased at an alarming rate, particularly since 1997. In 2005, upland rice varieties were introduced and demonstrated in the uplands of Fogera floodplains by the International Livestock Research Institute (ILRI). These included four rice varieties: *Nerica-1, Nerica-2, Nerica-3* and *Superica-1*, which were introduced from West Africa and the *Pawe* variety from Benshangul Region in Ethiopia. This monoculture of exotic cross-breeds of high yielding rice varieties has decimated the diversity of the indigenous crop varieties and probably had negative impacts on the biological diversity at all levels from ecosystem to species and gene pool. The impacts on both cultural and natural landscapes may be unsustainable in the long term and require longer-term studies than those warranted by the present survey.

2.6.2 Conservation of *Cyperus papyrus*

The *Cyperus papyrus* population of the swamp and marsh-land habitats of the wetlands has been locally threatened, both spatially and temporally. The rise and fall of the water level of the lake and the inconsistent flood frequency, flood depth and duration of the habitats, coupled with anthropogenic activities have had significant impacts on the decline of the population. Interviews with the local people confirmed that the papyrus population has reduced over the last 40 years, especially during the successive drought years of the 1970s and 1980s, but also due to fires and habitat loss. The village of Dengel Mender was given its name on account of the abundant papyrus in the area. Until 1984, remnant patches of the species were seen in the area. Scanty populations of the species are also found in pockets of habitats near the monasteries of Tana Kirkos and the Tsira Zion church, where they are conserved through religious consecration.

Offshore, viable populations of the species are only found in Estumet near Kunzila and at Ambo Bahr. From the past distribution, current state and from the likely trends of habitat fragmentation, it is possible that the population of the species will inevitably disappear unless habitat conservation and rehabilitation measures are undertaken. The efforts by some investors to complement the natural stock of *Cyperus* with *in situ* plantations in the western catchment should be supported only after a thorough EIA and as a backdrop to enhance employment opportunities in the region.

2.6.3 Conservation of other wetland vegetation communities

Based on IUCN wetland categories, the wetland plant species surveyed were categorized into intolerant, weakly tolerant, moderately tolerant and tolerant, based on their flood tolerance (Table 2.8). The degree of resilience and susceptibility to water level fluctuations due to development projects should be evaluated against the economic and social values that the wetland plants can accrue to the region.

Comment [CL11]: check numbering

Table 2.8. Flood/water tolerance scale for major wetland vegetation species in Lake Tana

Comment [CL12]: check numbering

Intolerant	Weakly tolerant	Moderately tolerant	Tolerant
Cynodon dactylon	*Crinum schimperi*	*Hygrophila auriculata*	*Cyperus papyrus*
Elucine indica	*Gnaphalium rubrifolium*	*Commelina difusa*	*Typha latifolia*
Elucine multiflora	*Trifolium* species		*Cyperus rotundas*
Medicago polimorpha			*Cyperus latifolius*
Andropogon sorghum abyssinicus		*Cyperus esculantus*	*Nymphaea coerulea*
Oxygonium sinuatum		*Anagalis* spp.	*Leersia hexandra*
Datura stramonium	*Polygonium barbatum*	*Cyperus rigidifolius*	*Cyperus cyperoides*
Galinosoga parviflora	*Polygonium salicifolium*	*Guzotia scapra*	*Echinochloa ugandensis*
	Xantium strumarium	*Plectranthus* spp	*Persicaria setosula*
		Persicaria senegalensis	
		Persicaria lapathifolium	
		Anagallis serpentis	
		Achyranthes aspera	
		Celosia argentea	
		Ageratum conizoides	
		Ajuga integrifolia	

		Leucas abyssinica	
		Satureja paradoxa	
		Aeschynomene abyssinica	

Intolerant - Weakly tolerant*:* vegetation communities/populations that can survive flooding into growing season for a few days or weeks, but plants do not develop adaptations for low oxygen levels.
Moderately tolerant**:** vegetation communities/populations that can survive and grow in saturated conditions for several months of the growing season, but mortality ensues if flooding persists. Have some adaptations for living in low oxygen. Many tolerate flooding for one to three months, part of which occurs during the growing season.
Tolerant*:* vegetation communities/populations that can survive and grow in saturated conditions for long periods of time and have adaptations for living in low oxygen environment. Under saturated conditions, these species have low oxygen compensation. Some species can survive conditions of flooding, and they regularly tolerate six months of inundation annually, including part of the growing season.

Under the scenarios listed below, the response of the wetland plants to flooding or desiccation could be graded as follows:

(i) Flood tolerant vegetation associations
Wetlands that are degraded have the capacity to recover in a season or two if the hydrological regime conditions of the basin are well managed. *Cyperus* papyrus for example will emerge as long as permanently water-logged habitats exist. Other sedges will be able to regenerate accordingly depending on the length of time that water stays in an area. Given these various conditions for tolerance, sections of Fogera Wetlands could be zoned for regeneration.

(ii) Succession of moderately flood tolerant species
These communities/populations can survive and persist after disturbance and grow in saturated conditions for several months of the growing season and have some adaptations to tolerate survival in low oxygen compensation thresholds. Many tolerate flooding for one to three months, part of which occurs during the growing season. With increasing flooding in depth and duration, abundance reduction and mortality of the species ensues because of their inability to tolerate low oxygen.

(iii) Succession of weakly flood intolerant species
Vegetation communities/populations that can survive flooding into their growing season for a few days or weeks and do not develop adaptation for low oxygen levels. Not tolerant of any flooding above the root crowns during the growing season, but flooding for one month annually may occur regularly during the dormant season. These vegetation communities do not have adaptations to grow in saturated soils during the flooding time.

(iv) Succession of flood intolerant species

Vegetation communities/populations that cannot survive even short periods of flooding/inundation into the growing season and have no adaptation for low oxygen levels. These vegetation communities will be easily eliminated during low water draw-down and any projects which anticipate this will have to take this threat into consideration.

Generally, human interventions that cause disturbance of the hydrological regime of the lake and its feeder rivers will have major deleterious effects on papyrus populations. Destructive effects caused by grazing, harvesting, removal of rhizomes for fire wood, fire burning and receding agriculture can be minimized by keeping the water level of the lake within its natural system.

Possible management options include (i) conserving remnant habitats/ecosystems close enough together to permit dispersal and (ii) linking remnant ecosystems with dispersal corridors.

2.6.4 Conservation of keystone species in the LTSB

The term 'keystone species' is defined as those species that play a critical ecological role in maintaining ecosystem structure or function than one would predict based on their abundance or biomass. Likewise, a keystone ecosystem is one whose role in landscape structure and function is greater than that predicted from its area.

Locating and identifying keystone species or ecosystems have become important ecological tasks and are commonly addressed in conservation biology due to their critical roles in conservation and management of ecosystem structures and functions. In Lake Tana, the small *Barbus* species are the main prey and thus play a keystone function in the food web interaction of the piscivorous species (de Graaf & Dejen, 2003).

The mosaic wetland ecosystems provide habitats for Palearctic migrant birds because of the bio-geographic linkage with the temperate ecological zone of Eurasia and North Africa. During the temperate winter, the associated wetlands provide habitats for an array of Palearctic migrant bird populations and hence provide a keystone ecosystem. The various permanent and seasonal rivers and streams are keystone habitats for riverine migrant fish spawners. The conservation implications of keystone species or ecosystems are significant as loss and fragmentation/degradation of keystone ecosystems results in functional disruption of an entire ecosystem. Therefore, keystone species and ecosystems that play critical ecological roles in the dynamics of ecosystem structures and functions, and those ecosystems which are at high risk of further decline, should receive the highest priority for conservation in the Lake Tana sub-basin.

A minimal critical area for an ecosystem is required that will accommodate an intact biological community with viable populations of most of its species. A minimum dynamic area is large enough to permit dynamic fluctuations while accommodating most species associated with the ecosystem's biotic community. Special attention needs to be given to protect and conserve those endangered, threatened, rare, narrow-habitat specialists that have key roles in ecosystem integrity through demarcation of a minimal critical area. Table 2.9 shows the assessment matrix used to delineate such habitats, as applied to the Lake Tana sub-basin. The matrix was used to prioritize the different habitats in the Lake and its sub-basin for conservation programs in the future.

Comment [CL13]: check numbering

Table 2.9: Habitats in the LTSB with high conservation needs (EPLAUA)

Comment [CL14]: Confirm whether the EPLAUA devised the matrix – is there a reference to be inserted here

Ecological Unit	Main ecological importance	Level of typical habitat structure[1]	Scale of Impairments[2]	Conservation Priority[3]
1.Sub-littoral and pelagic zones of the deep oligo-trophic open water body of the lake	Maintain genetic resources of the endemic fish communities in a dynamic and evolutionary state.	good	slight	1
2. Gilgel Abay River flat plains of the marsh and swamp wetlands and its siltation zone.	Important area for globally threatened birds; biome-restricted bird assemblages; huge waterfowl congregations; temperate wintering birds; papyrus conservation and hippopotamus populations. Corridor path for endemic and threatened fish species; provide spawning grounds	good	slight	1
3. Rocky and vegetative sections of littoral zones of the lake along shoreline from Ambo Bahr to Gilgel Abay	Conserve keystone small barbus species important in energy flows to the higher trophic levels; conserve critically endangered fish spp; provide habitats for lacustrine endemic fish spp.	mediocre to average	medium	1
4. Gumara River mouth and its upstream tributaries	Corridor path for riverine endemic and threatened fish species; provide breeding & spawning grounds	mediocre to average	major	1
5. Rib River floodplains of Sherer and Wollela seasonal swamp wetlands and its ox-bows	Area for globally threatened and temperate wintering birds; important source of food for fishes; spawning ground, nursery and/or migration path	mediocre to average	major	1
6. Dirma and Megech River mouths/plains and their upstream tributaries	Corridor path for endemic and threatened fish species and spawning grounds	mediocre to average	major	1
7. Gelda River siltation zone and its tributaries	Corridor path for endemic and threatened fish species and spawning grounds	mediocre to average	major	1
8. Enfranz River mouth and its upper middle course	Area for globally threatened and temperate wintering birds; corridor path for endemic and threatened fish species and spawning grounds	good	major	1
9. Upper Blue Nile River basin and its immediate surroundings	Unique natural feature/waterfall; riverine forest wetlands; area for globally threatened and temperate wintering birds; important hippo and crocodile populations; vulnerable papyrus populations; green corridors connecting the lake and	good	major	1

Ecological Unit	Main ecological importance	Level of typical habitat structure[1]	Scale of Impairments[2]	Conservation Priority[3]
	riverine systems			
10. Ephemeral River Mouths of Sege, Abagenen, War and Kimo	Corridor path for migration of riverine, endemic and threatened fish species; provide spawning grounds	mediocre to average	major	2
11. Ambo Bahr-Gubiza marsh and swamp wetlands	Area for globally threatened birds and biome-restricted assemblage temperate wintering birds; endangered populations of hippo; vulnerable populations of papyrus	good	medium	1
12. Abagenen River plain/ Biching wetland/Dembia	Area for globally threatened birds and biome-restricted assemblage of temperate wintering birds	good	major	2
13. Arable and semi-arable seasonal wetlands of Fogera floodplains	Maintain agro-biodiversity; area for globally threatened and temperate wintering birds	mediocre to average	major	3
14. Gulf of Bahir Dar shorelines from Chara Chara through Gerima marsh & swampy wetland to Zeghe Bay	Vulnerable populations of papyrus; area for globally threatened birds; biome restricted assemblage of birds; aggregated waterfowls; temperate wintering birds; hippos	good	major	3
15. Zeghe peninsula forestland	Remnant forest biodiversity; historic & cultural resources; highland biome restricted bird assemblages	excellent	major	1
16. Dega Estifanos	Remnant forest biodiversity; historic & cultural resources; biome restricted assemblage birds	excellent	slight	1
17. Tana Kirkos and its surrounding islets	Remnant forest biodiversity; historic & cultural resources; provide nesting for huge waterfowl colonies	excellent	slight	1
18. Korata Mariam forest	Remnant forest biodiversity; biome restricted assemblage birds	excellent	slight	1

Key to table:
1 = excellent, good, mediocre to average
2 = slight, medium, major, irreversible, disturbed (not reversible)
3 = relative conservation ranking from 1 to 3, where 1 represents prioritized habitats subject to strict protection, 2 represents habitats that require seasonal restrictions to public access, 3 represents habitats that seek conservation through active habitat management/intervention

It can be concluded that most lake habitats need considerable conservation efforts to protect the survival and continuity of the unique species-flocks of *Barbus*, the last remaining type of this fish in the world. There is also urgent need to protect the river mouths as they serve as breeding passages for fish and the emergent macrophyes stands. The islands need to be protected to conserve the herpetofauna, invertebrates, birds and forests from human intervention and other anthropogenic impacts in general. Loss of reeds by removal and fires should be avoided, as the macrophytes play an indispensable role in the Lake Tana ecosystem. The hippopotamus is severely endangered and should be protected. Conservation priority is low for habitats such as the Fogera floodplains and Bahir Dar Zuria wetlands on account of the irreversible harm done in these habitats. However, efforts should continue in order to mitigate and avert activities that may deteriorate these ecosystems further and lead to their total demise. Proper management plans should be put in place for such impacted habitats and others in imminent danger. Investment opportunities are very limited in these high-priority conservation zones in the LTSB. Any management plan for the Lake Tana and its sub-basin should give high consideration to balancing the needs of conservation with the development drive in the region.

2.7 Information requirements for LTSB

The following are main subject areas requiring additional information and research.

a) General limnological studies should focus on:
- details of the benthic organisms
- detailed periphyton and macrophyte production
- nutrient dynamics of the lake, the quantity of sediment, nutrients, organic matter, allochthonous/autochthonous input into Lake Tana
- water quality studies
- the geology, lake sediment, wetland-lake ecotone and lake level dynamics

b) Studies on macrophytes should consider:
- the extent of macrophyte expansion and its impact on lake level changes, with particular emphasis on submerged macrophytes
- the contribution of floating and submerged macrophyte to the lake water budget and evaporation

c) Food chain analyses should investigate the roles of lower trophic levels such as plankton and benthos to the food web in the Lake Tana system

d) Biological studies should focus on:
- the reproductive segregation and taxonomic resolution of the Barbus and other fish species
- the taxonomy and distribution of herpetofauna and invertebrates in the wetlands
- verification of the eligibility of some wetlands as important bird areas (IBAs) with a view to securing their conservation status

e) The impact of climate change on the biodiversity of the LTSB should be investigated

f) Studies on hydrological functions and hydrological contribution of wetlands, such as:
- recharge and discharge into the wider Blue Nile basin
- the extent of wetland loss and restorability
- the modality and regulation of water usage in wetlands

- the impacts of drainage, livestock encroachment (trampling) and high flooding on the wetlands

g. the ecological and economic valuation of wetlands should be determined more precisely

2.3.8 References

Bekele A, *et al*. (1993). Useful trees and shrubs of Ethiopia: Identification, propagation and management for agricultural and pastoral communities. Publ. Regional Soil Conservation Unit, SIDA: 474pp

Barbour M.T, Gerritsen J, Snyder B.D, & Stribling J.B. (1999). Rapid Bio-assessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. Available from: http://www.epa.gov/owow/monitoring/rbp/

Birru Y, Hurni H, & Zeleke G. (2004). Processes of land degradation in the Lake Tana Basin (LTB), Amhara Region, Ethiopia. Proceedings of the Symposium on Lake Tana watershed management; 2004 September 24-25; Bahir Dar University. Bahir Dar: Ethiopia. p. 5-12.

Christensen V, & Walters C. (2000). Ecopath with Ecosim: Methods, capabilities and limitations. In: Methods for assessing the impact of fisheries on marine ecosystems of the north Atlantic (Pauly and Pitcher, eds.). Fisheries Center Research Reports. 8(2) p. 120-140

Curtis PJ, & Schindler DW. (1997). Hydrologic control of dissolved organic matter in low-order Precambrian Shield lakes. *Biogeochem*. 36: 125-138.

Dearing JA, & Foster IDL. (1993). Lake sediments and geomorphological processes: Some thoughts. In: J McManus and RW Duck (eds.) *Geomorphology and sedimentology of lake reservoirs.* New York, John Wiley and Sons. pp 5-14.

de Graaf M, Dejen E, Sibbing FA, & Osse JWM. (2000). The piscivorous barbs of Lake Tana (Ethiopia): Major questions on their evolution and exploitation. *Netherlands Journal of Zoology* **50***:* 215-223.

de Graaf M. (2003). Lake Tana's piscivorous *Barbus* (Cyprinidae, Ethiopia): Ecology, Evolution, Exploitation [PhD thesis]. Wageningen University, The Netherlands.

de Graaf M, Machiels MAM, Wudneh T, & Sibbing FA. (2004). Declining stocks of Lake Tana's endemic *Barbus* species flock (Pisces: Cyprinidae): natural variation or human impact? *Biological Conservation*. **116**: 277-287.

Dixon AB, Hailu A, & Wood AP. (eds). In: Proceedings of the wetland awareness creation and activity identification workshop. Amhara National Regional State. 2001 January 23. Bahir Dar, Ethiopia: 33-34.

Dejen E. (2003). Ecology and potential for fishery of the small barbs (Cyprinidae, Teleostei) of Lake Tana, Ethiopia [PhD thesis]. Wageningen University, Wageningen, The Netherlands.

Eshete Dejen, H. A. Rutjes, M. de Graaf, L. A. J. Nagelkerke, J. W. M. Osse & F. A. Sibbing, (2002). The 'small barbs' *Barbus humilis* and *B. trispilopleura* of Lake Tana (Ethiopia): are they ecotypes of the same species? *Environmental Biology of Fishes* 65: 373-386.

Food and Agriculture Organizatiion (FAO, 1988): National Parks Planning: a manual with annotated examples: pp105

Greenwood, P.H. (1976). Fish fauna of the Nile. In: *The Nile, Biology of an ancient river* (Rzoska, J. ed.) The Hague, Dr. W. Junk publishers.

Howell, P.O. and Allan, P (1994) *The Nile: Sharing a scarce resource*. Cambridge University Press.

IUCN (2003): Wetlands of Ethiopia: Proceedings of a Seminar on the resources and status of
Ethiopia's Wetlands. pp 116

Jeppesen, E., M. Sondergaard, B. Kronvang, J.P. Jensen, L.M. Svendsen and T.L. Lauridsen (1999) Land and catchment management in Denmark. *Hydrobiologia* 396: 419-432.

Kalff, J. (2002). *Limnology: Inland waters Ecosystems.* Prentice-Hall.Inc. USA.

Lake Net, (1999). Available from: http://www.worldlakes.org

Mahon, R. (1984) Divergent structure in fish taxocenes of North Tamperate streams. *Can. J.Fish. Aquat. Sci* 56:329-347.

Ministry of Water Resource (2002): Study Report on the causes of Water Level Reduction of Lake Tana in 2002, Amharic version, MWR, Addis Ababa: PP 10.

Mohr, P.A. (1962). *The geology of Ethiopia*. Addis Ababa. University College of Addis Ababa press. 268 pp.

Molla, M. and T. Menelik, (2004). Environmental Impact Assesment for Unusual Reduced Water Level of Lake Tana. In Proceedings of the Symposium on Lake Tana watershed management. Lake Net, USA: 35-48.

Moss, B. (1994) Brackish water and freshwater shallow lakes - different systems or variations of the same theme? *Hydrobiologia* 275/276:1-14.

Muluneh, A, A. (2005) Ecological importance of aquatic macrophytes in the southern part of Lake Tana. Report of the Amhara National Region Rehabilitation Development Organization (TIRET)

Nagelkerke, L. A. J., F. A. Sibbing, J. G. M. van den Boogaart, E. H. R. R. Lammens & J. W. M. Osse, (1994). The barbs (*Barbus* spp.) of Lake Tana: a forgotten species flock? *Environmental Biology of Fishes* 39: 1-22.

Nagelkerke, L. A. J., M. V. Mina, T. Wudneh, F. A. Sibbing & J. W. M. Osse, (1995). In Lake Tana, a unique fish fauna needs protection. *Bioscience* 45: 772-775.

Omoding, J., Otim, T., Etiang, P. & Mutekanga, N. (1996). Inventory of wetland biodiversity in Uganda. Activities, methodologies and results. National Wetlands Programme, Kampala.

Roggeri, H. (1995) *Tropical freshwater wetlands*. Kluwer Acad. Press.

Roth, N.E. (1994). Land use, riparian vegetation and stream ecosystem integrity in an agricultural watershed (Univ. Michigan Thesis). In: J.D.Allan, 1995. Stream ecology structure and function in running waters. London, Chapman and Hall.

Rzoska, J. (1976). *Lake Tana, headwater of the Blue Nile. In the Nile, Biology of an ancient river* (Rzoska, J. ed.) The Hague, Dr. W. Junk publishers.

Scheffer, M. (1998). *Ecology of shallow lakes*, I: Chapman and Hall. London. 0-357.

Scheffer, M., S.R. Carpenter, J.A. Foley, C. Folke, and B. Walker (2001) Catastrophic shifts in ecosystems. *Nature* 413:591-596.

Seyoum Mengestou and Fernando, C.H. (1991). Biomass and production of the major dominant crustacean zooplankton in a tropical Rift Valley lake, Awasa, Ethiopia. *J. Plankton Res.,* 13, 831-851.

Shibru Tedla (1995). Protected Areas Management Crises in Ethiopia. *Walia* 16 : PP 17 30.

Taddese Fetahi and Seyoum Mengistou (2006). Trophic analysis of Lake Awassa (Ethiopia) using mass-balance Ecopath model. *Ecological Modelling* 201: 398-408.

Talling, J. F. & J. Lemoalle, (1998). Ecological dynamics of tropical inland waters. Chapter 3.1. Resource utilization and biological production - Primary utilization: energy: p. 82-117. Cambridge University Press, Cambridge, UK. 441 pp.

Talling, J.F. and Talling, I.B. (1965). The chemical compositions of African lakes. *Int.Rev. Gesamten. Hydrobiol* 50: 421-463.

Talling, J.F. and J. Rzoska. (1967). The development of plankton in relation to hydrological regime in the Blue Nile. *J. Ecol.* 55: 637-662.

Tesfaye Wudneh. (1998). *Biology and Management of Fish Stocks in Bahir Dar Gulf, Lake Tana, Ethiopia*. PhD thesis, Wageningen Agricultural University. 143 pp.

Vijverberg, J. (1989). Culture techniques for studies on the growth, development and reproduction of copepods and cladocerans under laboratory and *in situ* conditions: a review. *Freshwat. Biol*., 21, 317-373

Wallsten, M. and P.O. Fergsen (1989). The effects of increased water level on aquatic macrophytes. *Journal of Aquatic Plant Management* 27:32-37.

Wetzel, R. G., (2001). *Limnology: Lake and river ecosystems*. 3rd edition Academic Press, San Diego, 1006 pp.

Woldegabriel G., (2002). Ecological Threats of Lake Tana freshwater ecosystem and its management consideration with the Biosphere Reserve Concept : a workshop paper presented on Fish and Fisheries of Lake Tana : Management and Conservation*, ARARI,* Bahir Dar: pp10

Wondie A. (2006). Dynamics of the major phytoplankton and zooplankton littoral communities and their role in the food-web of Lake Tana, Ethiopia. [PhD dissertation]. Addis Ababa University. 161 pp.

Wondie A, & Mengistou S. (2006). Duration of development, biomass and rate of production of the dominant copepods (Calanoida and Cyclopoida) in Lake Tana, Ethiopia. *SINET: Ethiopian Journal of Science*. 29 (2): 107-122.

Wondie A, Mengistou S, Vijverberg J, & Dejen E. (2007). Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and water transparency. *Aquatic Ecology*. 41: 195-207.

World Habitat Society (2004). A proposal for a Potential UNESCO Biosphere Reserve in the Lake Tana/Blue Nile area, Ethiopia. pp 5. World Habitat Society, Environmental Services, Germany.

Zerfu, H. (2004). Socio-ecological Significance and Management Constraints o Wetlands in the Amhara Regional State: In: Proceedings of the National Consultative Workshop on the Ramsar Convention and Ethiopia, March 18-19/2004, Addis Ababa, Ethiopia pp 51-61.

Flora of the Lake Tana Sub-Basin (LTSB)

Prof. Zerhin Woldu
Department of Biology, National Herbarium
University of Addis Ababa
P. O. Box 3434
zerihunw@bio.aau.edu.et

3. Introduction

Ethiopia is a country with high biodiversity and distinctive ecosystems and the natural resource base is critical to the economy and the livelihood of a high percentage of the population. Human activities, such as direct harvesting of species, introduction of alien species, habitat destruction, and various forms of habitat degradation (including environmental pollution), have caused dramatic losses of biodiversity; however, despite its importance few people give biodiversity loss the attention that it deserves.

Agriculture accounts for 50% of GDP, 85% of foreign exchange earnings and supports 85% of the workforce, albeit insufficiently. There are several studies that deal with land degradation at the national level in Ethiopia (EHRS-FAO 1986; Sutcliffe 1993; Ethiopian Forestry Action Plan 1993; and Keyser & Sonneveld 2001). Estimates vary considerably but direct losses of productivity from land degradation are about 3% of agricultural GDP. With a population growth rate of 2.9% this is a critically important figure (CSA, 1984).

Approximately half of the highlands are thought to be significantly eroded (Hawando, 1997), with an additional 20,000 km^2 requiring restoration to sustain future cropping. Population pressure, leading to inappropriate agricultural practices, such as deforestation, cultivation on steep lands and overgrazing, is blamed for 80% of the erosion (Figures 3.1 & 3.2). Note the high human and livestock population densities in the LTSB. The fact that 85% of the population of Ethiopia is rural and will remain so in the years to come implies that the rural areas will carry an even greater demographic burden than at present. This will be reflected in the rapid rate of deforestation of the limited forest resources of the country.

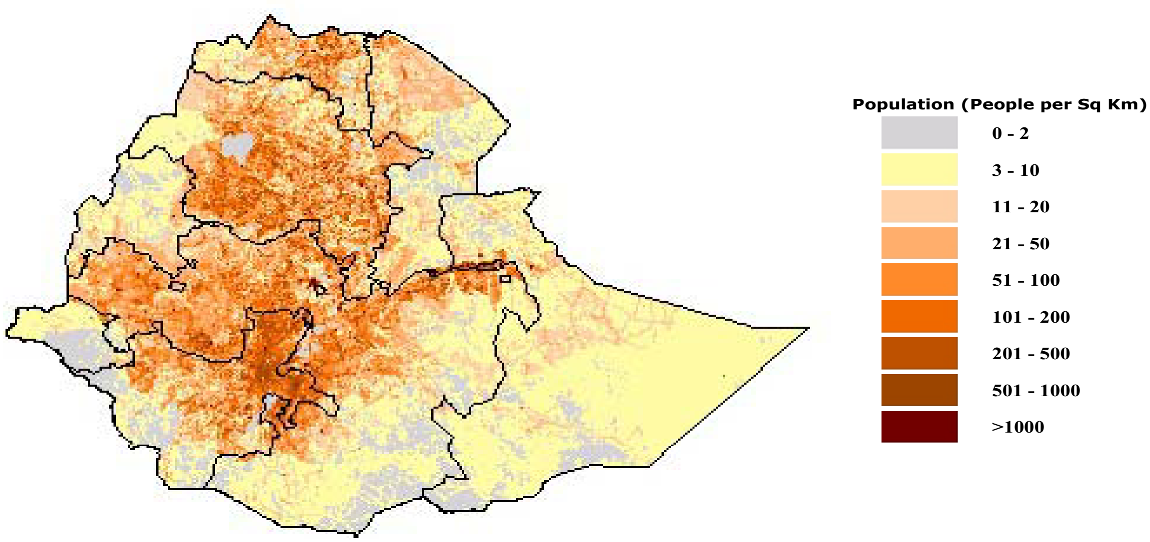


Figure 3.1 Population map of Ethiopia

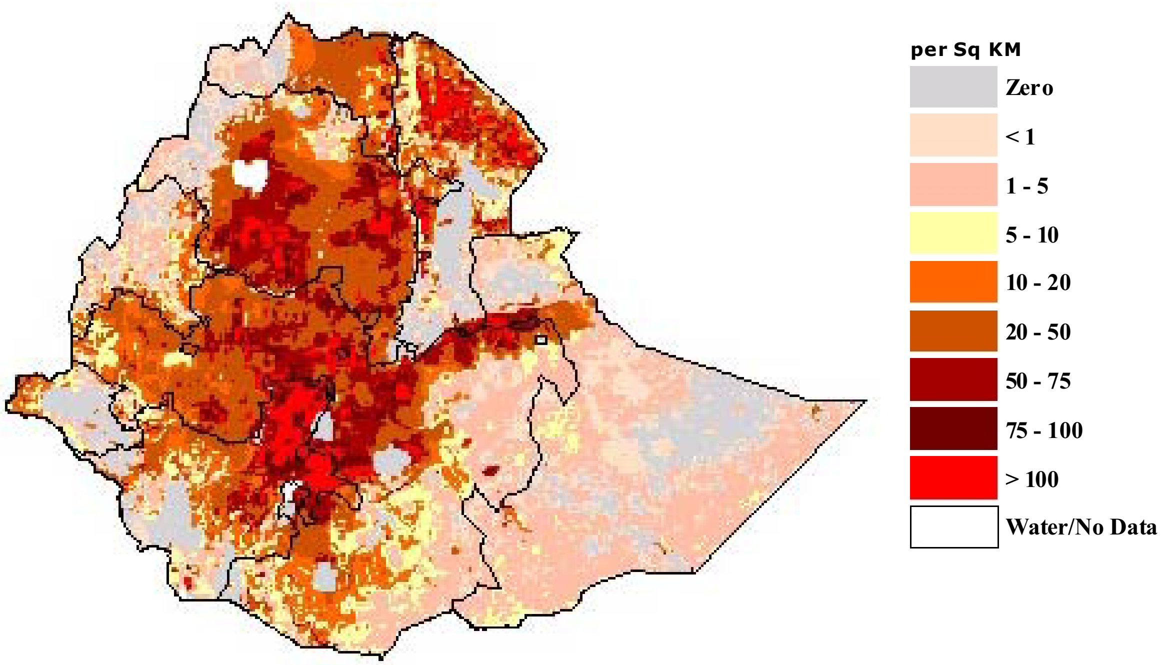


Figure 3.2 Livestock population of Ethiopia

According to Sutcliffe (2006), the potential annual supply of woody biomass in 2000 was 77 million tons while the annual consumption (including wood as charcoal) was 54 million tons. This is unsustainable resource extraction. There is an annual loss of 65,540 ha of high forest, 91,400 ha of woodland and 76,400 ha of shrubland due to land-clearing for agriculture and settlement, which amounts to woody biomass losses of approximately 3.5 million tons (Sutcliffe, 2006). As a result, ecosystem functions which encompass biodiversity, hydrological regulation, carbon sequestration and soil fertility loss will continue impinging on the biodiversity and lead to the extinction of many unique flora and fauna of the country and the world at large.

All physical and economic evidence shows that loss of land resource productivity is an important problem in Ethiopia and that with continued population growth the problem is likely to be even more important in the future. The Government of Ethiopia has recently finalized the Plan for Accelerated and Sustained Development to End Poverty (PASDEP[1]). PASDEP reflects a consensus that pro-poor growth is a fundamental priority for development. PASDEP advocates continuing to pursue the strategy of Agricultural Development Led Industrialization (ADLI), but

---

1 PASDEP is centered around eight elements: (i) commercialization of agriculture and promoting rapid non-farm private sector growth; (ii) geographical differentiation; (iii) population; (iv) gender; (v) infrastructure; (vi) risk management and vulnerability; (vii) scaling up service delivery; and (viii) employment.

with important enhancements to capture the private initiative of farmers and support the shifts to diversification and commercialization of agriculture.

A private sector push, especially on exports, is advocated to create jobs and reduce foreign exchange constraints. The development of Ethiopia depends upon its capacity to address the interrelated issues of food security, poverty alleviation, environmental degradation, high population growth rate and agricultural development constraints. Just as agricultural development needs to integrate poverty alleviation and environmental conservation, so other sectors of the economy need to integrate agricultural development.

As degradation and loss of soil nutrients are the major constraints to agricultural production, and as abating rural poverty is a government priority, it is necessary to intensify production using all sustainable options. The concept that infrastructure development and environmental protection should be managed in an integrated manner is universally accepted. This is in line with the national policy that is put in place to promote and ensure that the impact of any developmental activity on the environment is minimized, or prevented at best, in order to maintain an environmental system free of induced stress.

LTSB is a highly settled area with associated pressures on its natural resources, including the vegetation cover and the floral diversity. The floral, ecosystem and landscape diversity need to be documented for informed decision on their rehabilitation taking into account the need for poverty alleviation and food security without compromising environmental safety.

The possible consequences of human interferences have to be recognized early enough and should be taken into account for the design and implementation of mitigation actions. Paying adequate attention to environmental issues from the outset will: help to avoid unnecessary environmental costs and delay in implementation; provide a formal mechanism for inter-agency coordination to deal with concerns of affected groups; and play a major role in building capacity at a national level for management of environmental problems.

Overview of Vegetation Types of Ethiopia

Vegetation types were recognized following Pichi-Sermoli (1957) and Woldu (1999). Published volumes of the Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989; Edwards *et al*., 1995; Hedberg *et al*., 1997; Phillips, 1997) were used for the identification of plant species.

The LTSB makes part of the Afromontane Archipelago-like regional centre of endmism and extreme floristic impoverishment (White, 1983). The Ethiopian part of the Afromontane Archipelago is mapped as Undifferentiated Afromontane Vegetation. White (1983) argues that the majority of the tree species in this type are very wide spread. These include *Podocarpus falcatus*, *Prunus africana, Hagenia abyssinica, Olea europeaea* subsp. *cuspidata* and *Juniperus procera* (which are also common in the LTSB). Pichi-Sermoli (1957) classified the area surrounding Lake Tana (which is a large portion of LTSB) as "*Various types of Savanna*". The same area is classified as *Hyparrhenia* associated with savanna by Ratray (1960), based on the composition of the grass flora.

Friis (1992) presented 163 maps, using records going back two hundred years, showing where specimens of the different tree species in Ethiopia have been collected. According to Friis (1992), the southern shore of Lake Tana and the general area around Tis Issat Falls have been relatively well collected.

Recent reports on the vegetation of LTSB include the study of the impacts of Tis Abay II Hydropower Project (Woldu 1996; Edwards 2000; SMEC International Ltd 2007), which focused on the riverine vegetation between Lake Tana and Tis Issat Falls through fieldwork and using the distribution maps of trees found in Friis's 1992 report.

3.1 Objectives

The main objective of this work was to describe the flora of the LTSB.

Specific objectives were to:

- describe existing floral, ecosystem and landscape biodiversity
- provide baseline data for an environmental monitoring and management plan
- identify the threats and suggest importance of managing biodiversity with respect to plants.

3.2 Methods

The study focused mainly on compilation of both qualitative and quantitative data on the flora of the LTSB in order to provide an assessment of the prevailing situation and its implications for the future.

Secondary Data and Literature Review

Secondary information was obtained from various relevant offices and from a review of both published and grey literature. Pertinent policies, laws, strategies and conventions were sourced for this study.

Sampling

Flora refers to all plant life occurring in an area or time period, especially the naturally occurring or indigenous plant life. This study of the flora of the LTSB constituted a comprehensive description of the plant species, including their abundance, their habitats, spatial distribution, ecological amplitudes, disturbance factors and regenerative capacities. The study involved a whole gamut of activities aimed at clarifying the link between the ecology of the flora and livelihoods of communities that are directly or indirectly dependent on them, as well as the relationship between the flora and the fauna of the area. The result of the study is not merely a list of plant species occurring in time and space. The economic and scientific importance of the flora and their management techniques, including the processes of rehabilitation of the degraded areas, were part of the information compiled. The secondary and primary data collected were integrated to provide useful information on the flora of the LTSB.

Vegetation was sampled following the LTSB land-use map described in Chapter 1. A reconnaissance survey was conducted to habitat types so that focus could be made on these types identified visually. Twenty seven sites were selected in the different parts of the LTSB for sampling. In each habitat type five *relevés* were sampled. The samples included inventory of the species and their relative cover-abundance in 400 m^2 of the vegetation for forest or shrub, and 16 m^2 for grassland or shrubland, using the Braun-Blanquet cover abundance scale (van der Maarel, 1979). The averages of these *relevés* were pooled for each vegetation type. Most plant species were identified during the field observation. Plant specimens were also collected to verify identity of unique species and those that were sterile. Species identification of those species recorded with uncertainty or not identifiable in the field was checked in the National Herbarium of Addis Ababa; species authority was obtained from the published Volumes of the Flora of Ethiopia and Eritrea. Garmin Global Positioning System was used to locate specific areas/sites and a Thommen Classic Altimeter was used to measure altitude.

Local people were consulted whenever possible about their view on the conservation of the vegetation and the challenges of conservation.

Discussions with GOs and NGOs

Discussions were held with the following governmental and non-governmental stakeholders in the LTSB:

- Ministry of Water Resources
- Tana Transport Enterprise, Department of Marketing
- General Manager of EPLAUA
- Parks Devolvement & Protection Authority (PADPA)
- Bureau of Agriculture and Rural Development – Soil and Water Conservation
- Lake Tana sub-basin, Forestry division
- Amhara Micro Enterprises
- USAID Integrated Watershed Research and Extension
- AMAREW
- Sustainable Water Harvesting and Institutional Strengthening in Amhara (SWHIHA)
- Amhara Food Security Office
- Director of Natural Resources (ARARI)
- Lake Tana Research Center
- UNDP Advisor to the Mayor of Bahir Dar

EPLAUA has initiated six projects, some of which have been completed. The projects include:

1. Lake Tana Watershed project
2. Reconnaissance survey of Lake Tana
3. Zeghe Peninsula natural forest protection and development
4. Lake Tana ecosystem
5. Crop Pests around Lake Tana
6. The effect of lake level fluctuation and the reduction of water in the lake on wetland and agricultural land

3.3 Results and analysis

3.3.1 Sampling sites

The coordinates and elevations of the sampling sites are given in Table 3.1 below.

Table 3.1 Location and coordinates in degree decimal of the sample sites

LOCATION	LATITUDE	LONGITUDE	ALTITUDE m asl
Blue Nile River (Abay)	11.539	37.402	1760
Azezo	12.540	37.410	2056
Bahir Dar	11.590	37.380	1911
Chiwahit	12.330	37.210	1911
Delgi	12.200	37.040	1802
Deq Island	11.920	37.260	1802
Enfranz	12.360	37.260	1926
Enfranz wenz	11.620	37.300	1850
Wetland	11.940	37.600	1882
Gerima Wetland	11.610	37.374	1911
Gorgora Hill	12.235	37.305	1846
Gorgora Hotel	12.258	37.308	1832
Gumara River	11.870	37.610	1846
Hamusit	11.790	37.550	1926
Kola Diba	12.420	37.320	1829
Kunzila	11.880	37.030	1829
Maksegnit	12.350	37.560	2280
Serse Dingil Guzara Palace	12.330	37.620	2294
Taragedam	12.196	37.809	2232
Teragedam Road	12.189	37.783	2232
Teragedam top	12.198	37.783	2298
Wawa Fodder	12.273	37.320	1795
Wawa Pump area	12.338	37.373	1799
Zeghe Ararat	11.700	37.350	1799
Zeghe forest	11.690	37.340	1886
Zeghe Wegelsa Terara	11.621	37.330	1850
Zeghe Wetland	11.720	37.320	1914

The map of the Lake Tana sub-basin and the location of the sample points as well as other relevant information are shown in Figure 3.1. The sample sites are represented by the yellow spots on the map with proposed future reference points for follow-up to these vegetation studies.

Figure 3.1. Map of Lake Tana Sub-basin showing locations of vegetation sampling points

3.3.2 Vegetation Types

This study found 244 species in 58 families in the LTSB (see Appendix 3.1 for the complete list). Of these 244 species, only 10 (4%) are endemic to the LTSB (see Table 3.2), of which only one (*Ruttya speciosa*) is classified as Vulnerable according to IUCN categories.

Table 3.2 Endemic vascular plant species and their IUCN vulnerability category

	Species name	**Family**	**Category**	**Endemicity**	**IUCN Category**
1	*Acanthus senni* Chiov.	Acanthaceae	Shrub	E	NT
2	*Cyperus atronervatus* Bock.	Cyperaceae	Herb	E	LC
3	*Erythrina brucei* Schweinf	Fabaceae	Tree	E	LC
4	*Maytenus serrata* Hochst.	Celastraceae	Shrub	E	LC
5	*Millettia ferruginea* Hochst. Baker	Fabaceae	Tree	E	LC
6	*Ruttya speciosa* Hochst. Engl.	Acanthaceae	Shrub	E	VU
7	*Sideroxylon oxanthus* Hutch. & Bruce	Sapotaceae	Shrub	E	NT
8	*Solanum marginatum* L.f.	Solanaceae	Herb	E	LC
9	*Vepris dainellii* Pich.Serm. Kokwaro	Rutaceae	Tree	E	LC
10	*Vernonia leopoldii* Sch.Bip	Asteraceae	Shrub	E	LC

Figure 3.2 shows the percentage representation of each plant category found in the LTSB.

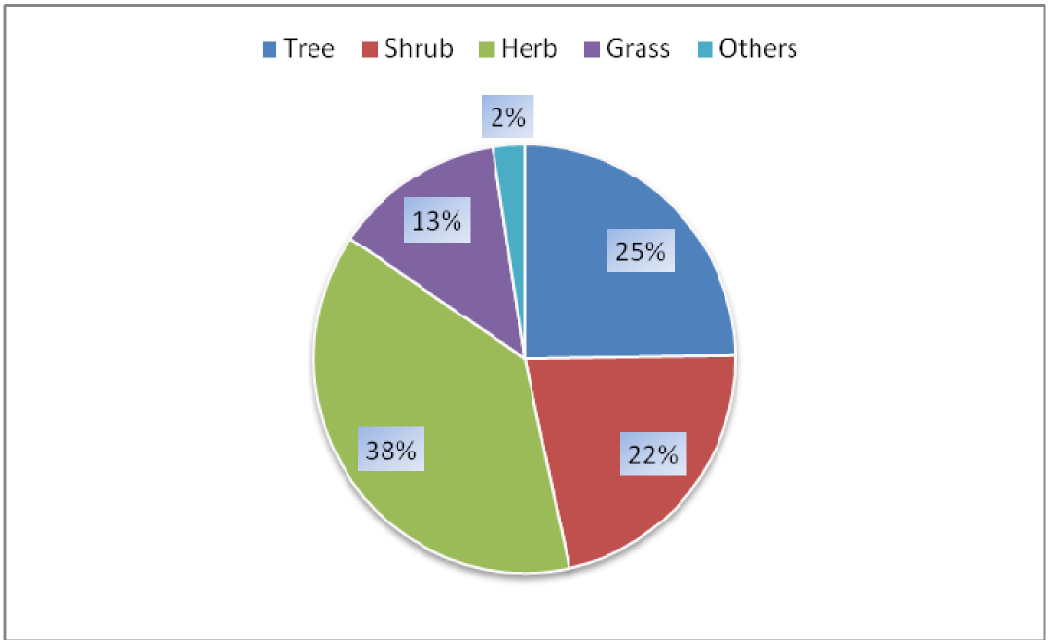


Figure 3.2 Plant categories encountered in the LTSB

The following six vegetation types were identified, based on visual inspection of the structure of the cover and the occurrence of dominant species:

a) submerged and floating vegetation of the lake shore and rivers
b) *Cyperus* and *Typha* beds
c) gallery forests of Lake Tana peninsula, islands and rivers
d) Fogera plain mixed vegetation
e) dry evergreen Afromontane forest and grassland
f) dry evergreen thicket and scrub

The detailed description and composition of these vegetation types are provided below.

a) Submerged and floating vegetation of the lake shore and rivers

This type of vegetation cover occurs around and in association with *Cyperus* and *Typha* beds expanding and contracting with the slope of the shore. It is well represented in Gerima wetland on the northern side of the city of Bahir Dar, at Zeghe wetland along the shore of Lake Tana and along Enfranz wenz.

Photo 3.1*Pistia statiotes* **and *Nymphaea caerulea***

Photo 3.2 *Nymphaea caerulea* **and *Echinochloa staginina*** **along the banks of the Blue Nile River**

The extent of this vegetation cover along the lake shore is vulnerable to waste water discharge and siltation into the lake.

Photo 3.3 ***Echinochloa staginina*** **and** ***Oryza longistaminata*** **submerged wetland near Zeghe**

b) Cyperus and Typha beds

Cyperus and *Typha* beds are an important feature of the shoreline around Lake Tana (photo 3.5), particularly along the eastern shore where the Lake floods regularly. These reed beds and swampy areas are important habitats for resident and migrant water birds (photo 3.4). They also provide ecosystem services in cleaning and regulating the quality of the water.

The dominant species are *Cyperus papyrus* and *Typha domingensis* both of which are used for making fishing boats, as fodder (photo 3.8), for roofing, matting (see photo 3.6) and as household utensils. The papyrus inflorescence (photo 3.7) is spread on floors and the ground during festivals and coffee ceremonies.

Photo 3.4 *Cyperus* and *Typha* bed at Kunzila and feeding waterfowl

Photo 3.5 *Cyperus* and *Typha* bed at Zeghe

Facultative wetland species occur on the peripheries of the cyperus and typha beds at Kunzila, as a result of human interference and livestock grazing.


Photo 3.6 Building fishing boats (Dengel) from *Cyperus papyrus* stems


Photo 3.7 *Cyperus papyrus* inflorescence on sale at the market in Bahir Dar

Photo 3.8 Harvested wetland grass transported for sale in the market at Bahir Dar

c) Gallery forests of Lake Tana peninsula, islands and rivers

This vegetation type is represented by the forests in Zeghe peninsula and on Dek Island and the woody remnants on the southern shore of Lake Tana and along the Blue Nile River to the Tis Issat Falls. These sites have a large number of species. It would appear that the local availability of ground water enables species normally found in the wetter western and south-western forests to grow in the Lake Tana area.

The following species have their northern limit at LTSB: *Albizia schimperiana*, *Cassia petersiana*, *Chionanthus mildbraedii, Euphorbia ampliphylla, Ficus ovata*, *Lepidotrochilia volkensii, Oxyanthus speciosus, Prunus africana, Rothmannia urcelliformis, Turraea holstii* and *Vepris dainellii*. These species give the gallery forest of Lake Tana and the riverine forest of the Blue Nile River additional value as they contain genetic material at the northern most end of their species range. Pichi-Sermolli and Sebald (quoted in Friis 1992) consider these forests to be special humid sub-types of the Ethiopian plateau Afromontane forest.

The endemics among the tree species include *Erythrina brucei, Millettia ferruginea* and *Vepris dainellii*. *Erythrina brucei* and *Millettia ferruginea* are both common plants which propagate easily from seed and grow fast. The endemics among the herb species include *Ruttya speciosa.*

Photo 3.9 *Mimusops kummel* fruit sold at Zeghe market

The forest includes a number of large trees that provide a range of products from timber to edible fruits. Edible fruits, which are eaten particularly by children, are collected from *Carissa spinarum, Cordia africana, Mimusops kummel*, *Diospyros mespiliformis*, *Phoenix reclinata*, *Syzygium guineense* and *Ximenia americana*, some of which are often sold in local markets. Changes in the moisture regime due to flow reduction in the main river can drastically affect the riverine forest and could result in the loss of these edible fruit trees. The leaves of *Sapium ellipticum* are used as livestock fodder.

The monasteries in Zeghe forbid crop cultivation or keeping livestock in Zeghe peninsula (Ashebir Aleme, pers.comm 2008). The people therefore are fully dependent on the forest and fishing in the area is increasing. The people also supplement their income by keeping bee hives and harvesting honey. There are currently 40 modern and 4,000 traditional bee hives in the forest at Zeghe, of which 21 and 105 respectively are occupied by bee colonies.

Photo 3.10 Harvesting firewood in Zeghe forest

During the field work in Zeghe forest, logging of *Ficus vasta* was observed (photo 3.10) and the communities (population of 6,717) confirmed their dependence on natural resources from the forest for their livelihood (photo 3.11).

Photo 3.11 Fuel wood on sale in Zeghe

Photo 3.12 Shade coffee grows under the Zeghe Forest canopy

Photo 3.13 *Coffea arabica* cultivated under Zeghe forest canopy

Photo 3.14 *Celtis africana* in Zeghe forest, a valuable tree requiring protection

Photo 3.15 A view of the eastern side of Zeghe peninsula

While the forest in Zeghe peninsula (photo 3.15) is relatively intact (attributed to the prohibition of crop cultivation and keeping livestock), that on Dek Island is patchy (photo 3.16) as a result of intensive agriculture where finger millet (*Eluesine coracana*) is widely cultivated. Coffee is also widely grown on the island with *Millettia feruginea, Albizia gummifera* and *Albizia schimperiana* providing the canopy for the coffee stands.

Photo 3.16 A view of the landscape in Dek Island

Plate 3.17 *Sapium ellipticum*, a multipurpose tree in Dek Island

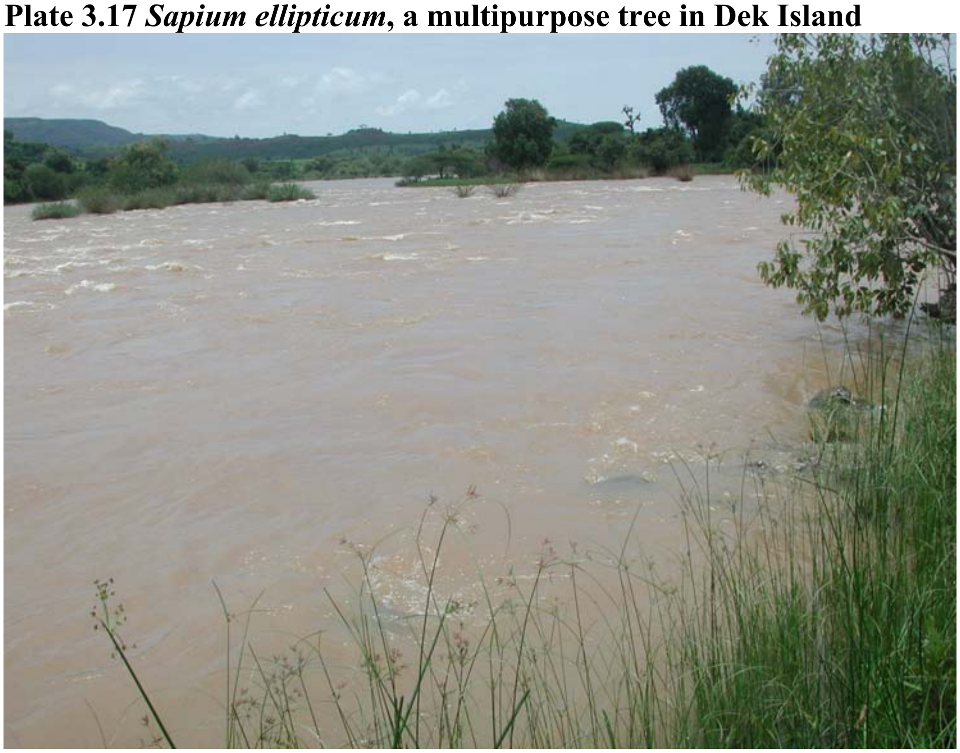


Photo 3.18 Riverine vegetation along the Blue Nile River

d) Fogera plain mixed vegetation

The Fogera plain is on the eastern part of Lake Tana and was previously covered with permanent and temporary wetland vegetation before it was converted to crop cultivation. The wetland part of the plain is dominated by species of the Family Cyperaceae and *Echinochloa stagnana*, while the degraded part has been invaded by different facultative wetland species and non-wetland species.

Fogera plain is being used as a demonstration site for rice production in the region and the country as a whole. In the 1970s, an agricultural research centre was established at Woreta with the aim to promote rice production. However rice production did not take off, partly due to the absence of a market and partly due to the lack of hulling mills to separate the husk from the crop. In the 1990s, two rice varieties "X-Gegna/White Rice" and "IIC-164/red rice" were introduced by the Bureau of Agriculture. X-Gegna received immediate acceptance by the farming communities and its cultivation expanded very rapidly. According to the elders of the local communities, rice is preferred to the indigenous crops because it can be used in a variety of way and is also more productive.

WoldeGabriel G/Kidan and Teka (2006) noted that upland rice was re-introduced in the flood plains by International Livestock Research Institute (ILRI) in 2005. These included four rice varieties: *Norica 1, Norica 2, Norica 3 and Superica 1*, introduced from West Africa and Pawe (Ethiopia, Benshangul). As a result of the quick shift to rice cultivation, biodiversity loss, through neglect of indigenous crops and associated cultural practices, is pronounced. Additional threats to biodiversity include expansion of farmland, as observed on the northern side of the lake near Gorgora at Wawa General Agricultural Enterprise (photo 3.20), where the consequence of rice cultivation will be the replacement of obligate wetland vegetation by mixed facultative species such as *Hygrophila auriculata* and *Cynodon dactylon* (photo 3.21).

Photo 3.19 Rice in Fogera plain

The wetlands around Lake Tana are considered to be the northern limit for *Oriza longistaminata,* one of the wild rice species occurring in Ethiopia that is important for production of rice hybrids, as they have natural resistance to fungal, bacterial and viral diseases. Wetland destruction for conversion to rice fields is interfering with the natural occurrence of this species.

Photo 3.20 Pumping water for Wawa General Agricultural Enterprise

Photo 3.21 Replacement of obligate wetland spcies by *Hygrophila auriculata*

The rest of the Fogera plain is subjected to overgrazing by the high livestock population of the area (photo 3.22). The vegetation cover in most places has been grazed to ground level and the surface of the soil is compacted. Both conditions lead to loss of soil condition and soil erosion.

Photo 3.22 High numbers of livestock on Fogera plain

e) dry evergreen Afromontane forest and grassland

The dry evergreen Afromontane forest and grassland vegetation covers most of the high ground in the eastern side of Lake Tana. Most of this is highly degraded and only some church yards and monasteries still maintain examples of intact forms of this vegetation type. Tara Gedam monastery provides a safe haven for the dry evergreen forest in LTSB, which consists mainly of trees such as *Acacia abyssinica, Albizia gummifera, Allophylus abyssinicus, Croton macrostachyus, Erythrina brucei, Juniperus procera, Olea europaea* subsp. *cuspidta, Maytenus obscura, Schefflera abyssinica* and *Podocarpus falcatus.* The shrub layer includes *Calpurnia aurea, Carissa spinarum, Solanum gigantum* and *Rosa abyssinica*. The endemics include *Erythrina brucei* among the trees and *Acanthus sennii* among the shrubs.

Photo 3.23 Degraded dry evergreen montane forest near Teragedam at Addis Zemen

Photo 3.24 A close up view of the dry evergreen montane forest of Tera Gedam

Photo 3.25 A 500 year old *Juniperus procera* in Tera Gedam

Photo 3.26 *Acanthus sennii*, a species endemic to Ethiopia occurring in Tera Gedam

Teragedam forest is managed by the 15th century monastery there. The current keeper of the forest, Aba Gebre Mariam of the Teragedam Monastery, believes that the Virgin Mary and the Son came through this sacred forest during their flight. According to the keeper, the biggest threat to the forest comes from the surrounding peasants. It is unclear which government department is responsible for patrolling the forest and bringing offenders to court. Due to the lack of wood in the area to make farm implements and for construction, the farmers consider that obtaining these resources from the forest is their right. Meanwhile, the monks and priests in the monastery consider it as their God-given obligation to maintain the forest. In order to satisfy the common interests and needs, government must increase its stake in forest management in this area.

f) dry evergreen thicket and scrub

This vegetation type occurs widely on hills and steep slopes of the LTSB and is mainly used for grazing. The distinctive feature of the dry evergreen thicket and scrub in Lake Tana sub-basin is the dominance of *Maytenus serrata* and *Calpurnea aurea*, instead of *Euclea racemosa* subsp *schimperi,* which is one of the dominant species in the same vegetation type in other parts of the country. In the LTSB, this vegetation is represented by patches on the hillsides in Azezo, Hamusit, Kola Diba, in the vicinity of Serse Dingil Guzara Palace, at Zeghe Wegelsa Terara (photo 3.28), Kola Diba and Chiwahit.

Photo 3.27 Remnant dry evergreen montane forest species in the dry evergreen scrub vegetation

Interestingly, some of the hillsides and plains covered by the dry evergreen thicket and scrub vegetation type are interspaced by some important tree species, including *Acacia albida*, *Cordia africana, Celtis africana* and *Ficus vasta* (photo 3.27). This is consistent with the findings of Alvarez (1970), a Portuguese Missionary who travelled extensively in northern and central Ethiopia between 1520 and 1527, that although the vegetation cover may have been lost due to a long history of human use, the gene pool persists, thereby increasing the chances of recovery, provided the right conditions can be facilitated.


Photo 3.28 Dry evergreen thicket and scrub at Wegelsa Hill

The dry evergreen thicket and scrub vegetation type is being subjected to a variety of human interference, including overgrazing, firewood collection and cultivation. As a result, this vegetation type, which probably was the result of degradation of the dry evergreen montane forest, is being further degraded and is rapidly losing its identity. In some sites, only the species such as *Dodonea angustifoloa, Pterolobium stelatum, Calpurnia aurea* and *Maytenus serrata* are prominent, while in other places some elements of the dry evergreen montane forest still persist (photo 3.27).

3.4 Discussion

Threats to floral and faunal diversity

The different vegetation types in the LTSB can have a great bearing on the diversity of the associated animal species and the soil types. The mammalian species that one would expect to see in the LTSB have virtually disappeared with the loss of vegetation cover. Trees provide roosting sites, seeds and fruits for birds, and shelter and food for large mammals. With the disappearance of these habitats, the animal species also disappear. The only birds frequently observed in LTSB are wetland birds, although some are considered to be crop pests in the Fogera plain. Mammalian crop pests frequently observed include baboons and vervet monkeys. Other mammals reported to occur in LTSB include hyenas, porcupines and bush pigs.

The plant biodiversity in the LTSB has been generally affected by long history of land use and the consequent land cover of the landscapes. The current threats to the remaining biodiversity are highlighted below:

(i) Encroachment of cultivation in the wetlands

A study by EPLAUA (2006) on birds as crop pests indicates that the encroachment of cultivation and expansion of agriculture into wetlands is posing a threat on the biodiversity. The replacement of biodiversity-rich habitats, which can serve as the natural feeding and nesting habitats of birds and other animals, with other crops can cause an ecological imbalance by, for example, altering the feeding behaviour of local and migratory species.

(ii) Expansion of cities

The expansion of cities, such as Bahir Dar, into the shoreline of Lake Tana will inevitably take up more wetland space and is an ever-growing threat to the biodiversity of the Lake. The inter-connectedness of the wetland vegetation and aquatic biodiversity should be emphasized as it makes the loss of wetland vegetation doubly critical.

(iii) Proposed Tana-Beles Hydro-Power Scheme

The Tana-Beles Hydro-Power scheme is under construction near Kunzila, on the western side of the lake. A tunnel is being excavated through the lake to allow water to flow into a tributary of the Abay (Nile) far downstream in the western lowlands of Ethiopia. The plan would result in the decommissioning of the existing hydroelectric scheme near Bahir Dar. Clearly, such a project can have the potential to affect lake water levels and hence marginal wetlands.

(iv) Proposed Dams on Tributary Rivers

Plans exist to build dams on the five main tributaries to the lake, principally for flood regulation purposes. The aim is to stabilize lake water levels at the lower end and prevent high flood levels in the rainy season. If successful, this could have very serious impacts on flood regimes and seasonal inundation of important marginal wetland areas. It is clear that any proposal to regulate such inundation is likely to have large-scale ecological implications.

v) Proposed Irrigation Schemes

Ethiopia's current emphasis on expanded investment in irrigation has benefited from achievements in recent years under the Nile Basin Initiative (NBI). Ethiopia's irrigation potential has been estimated at up to 3.7 million hectares, of which up to 2.2m hectares are located in the Nile Basin. The current irrigation projects on the Ethiopian side of the LTSB include those along the River Koga and several other rivers that are tributaries draining into Lake Tana. The Koga Irrigation and Watershed Management Project[2] is being developed along the River Koga and is one of the important projects that will significantly affect the land-use land-cover pattern. River Koga is a minor tributary of the Gilgel Abay River that flows into Lake Tana.

The Koga Project aims at an integrated development of the land and water resources of the area to increase rain-fed farming output, reduce soil erosion, increase timber production and permit development of irrigation infrastructure to enable double cropping of 6,000 ha. As the result of the implementation of the project, the small patches of the riparian forests and some patches of wetlands along the river will have to give way to a reservoir and the primary and secondary

[2] The proposed Koga Irrigation and Watershed Management Project is located within the Koga Basin in Mecha Woreda of Amhara Regional State. The Koga Dam will harness the water resources of the Koga River to irrigate 6,000 ha of the command area, as well as improve rain-fed agriculture, forestry, livestock, soil conservation, water and sanitation on a catchment area of 22,000 ha. The Blue Nile takes only 6.9% of its annual flow from the lake. A water balance analysis undertaken during the project preparation phase has shown that the project will use 44.8 mm^3 per annum which amounts to 0.09% of the Blue Nile's annual flow measured at the border. The effect of the project will be insignificant on the downstream riparian states.

canals. Some patches of evergreen scrub vegetation, as well as grasslands, will have to be converted to farmlands.

Two other irrigation schemes are under active development - one in the north between Gonder and the lake and the other in the east, to provide water for agriculture on the Fogera Plain. This latter scheme potentially involves a dam on the Rib River. In addition to these issues, there will be increased loss of wetlands to farming through the regression of papyrus beds that alter habitat and have strong negative effects on wider biodiversity.

vi) River Flow fluctuation

Riparian vegetation normally aggregates along a river bank to make use of the wetter conditions. Trees play important biological roles. For example, tree roots provide physical stability to the banks and leaf-fall may contribute to the nutrient demand of invertebrates and microphytes, which are important in the food web of the aquatic habitat. Birds find nesting and resting places on trees. Riparian trees may also be involved in sequestration of agrochemicals and high nutrient loads. No arboreal plant, however, is capable of tolerating complete submersion of its root system in water (except mangroves), as this prevents necessary root aeration. The trunks of some valuable income-generating fruit trees, such as *Ficus vasta, Mimusops kummel* and *Diospyros mespiliformis* are now visibly within the river. The regulation of the river flow for Tis Abay II hydropower plant may eventually kill the trees and a short-term decrease in the plant population can be anticipated. The damage may already have occurred. In the long run, however, the wetter conditions along the banks may increase new establishment and proliferation of the species. Mass kill of the trees can be anticipated when the water is diverted to the new Beles Hydropower Station if some water is not allowed to flow along its old course. Photos 3.29 and 3.30 show the volume of water and the features of the river bank before and after the completion of Tis Abay II Hydropower Plant.

Photo 3.29 Tis Issat Falls before completion of Tis Abay II Hydropower Plant

Photo 3.30. Tis Issat Falls after completion of Tis Abay II Hydropower Plant

vii) Crop species of LTSB

Thirty crop plant species from 15 families occur in the LTSB. Of these, 15 are annual while nine are perennial crop plant species. The number of crop plant species recorded in the LTSB may be indicative of the fact that the area is mainly an agricultural landscape. The number of crop plant species may also indicate the contribution of anthropogenic activities to diversity through the introduction of new species.

viii) Tree/shrub species in Bahir Dar

Forty-eight tree/shrub species were recorded in Bahir Dar, planted as "street trees", live fences or in gardens. The high number of tree/shrub species found may reinforce the view expressed above regarding the role of anthropogenic activities on biodiversity.

3.5 Conclusion

The Lake Tana sub-basin faces serious environmental degradation. Agriculture is the mainstay of the people and most of the land is already under cultivation, with the exception of some areas surrounding monasteries and churches. The conversion of the natural landscapes has resulted in the proliferation of many rapidly changing vegetation types. The resilience and resistance of the vegetation types to invasion is very low, making their existence temporary.

The proliferation of transient community types and those that can be considered to be in a desirable state are covered by 244 vascular and non-vascular plant species in 58 families assuming five different categories with different cover-abundance values. Upon initial inspection, the number of plant species found in the Lake Tana sub-basin could indicate rich diversity. However, their permanence is doubtful considering the rapid rate of land degradation that is taking place, which could result in species numbers increasing due to undesirable introductions, or decreasing due to habitat obliteration. Both options are harmful to the biodiversity; monitoring and evaluation are required for any informed decision-making.

3.6 Recommendations

a) Conservation initiatives at Lake Tana

Lake Tana and the associated Fogera Plain wetlands qualify as a Ramsar site under criterion 5 (ie, regularly supporting more than 20,000 waterbirds. The Lake also qualifies for management as a UNESCO Biosphere Reserve.

There is a need to strengthen the operation of The Lake Tana Environmental Protection Society, a local civic society created in February 2007, its principal aim being to raise awareness and promote the conservation of the lake, its wetlands and biodiversity.

b) Wildlife tourism

Tourism-related conservation efforts should be increased. Lake Tana's main reputation as a tourist destination is for its cultural heritage, in particular the monasteries. However, there is good reason for visitors to enjoy the rich wetland biodiversity around many parts of the Lake. Promotion as an ecotourism destination could focus on wildlife and/or on packages including cultural and natural heritage.

c) Watershed Management

The irrigation projects must as a matter of necessity incorporate the promotion of soil conservation techniques; rehabilitation of degraded sites; development of viable agro-forestry practices; protection of biodiversity; and promotion of water conservation measures.

The protection and sustainable management of watersheds, particularly around areas where irrigation structures have been installed, are important to stabilise the physical and biotic environment for the effective functioning of the ecosystem. Watershed protection and development can increase the life span of dams as well as improve available water for irrigation.

To protect and improve the floral biodiversity, it is important to protect and propagate some important riparian species, such as *Cordia africana, Mimusops kummel*, *Diospyros mespiliformis*, *Phoenix reclinata*, *Syzygium guineense* and *Sapium ellipticum*, and planting them along the reservoir and the canals as well as upstream and downstream of the Koga River. The same principle applies for all rivers and streams in theLTSB which have lost their natural vegetation cover.

References

Acres International Limited and Shawel Consult International, 1995. Koga Irrigation Project Feasibility Study, Main Report. Water Resources Development Authority. Addis Ababa. 99 p.

Alemayehu Abebe, 2006. GIS Application in suitability modeling for Livestock Production in Tana sub basin- Blue Nile River Basin. A thesis submitted to the School of Graduate Studies of Addis Ababa University in the partial fulfillment of the requirements for the Degree of Master of Science in GIS and Remote Sensing.

Alvarez, F. 1970. Portuguese embassy to Abyssinia during the years 1520-1527. Lord Stanley of Aderley (Translation and ed.). Burt Franklin Publisher, New York.

Anonymous, 1992. Ethiopia. National Report on Environment and Development. A report prepared for the UN Conference on Environment and Development, Rio de Janeiro, Brazil. Addis Ababa, Ethiopia.

van der mMaarel, E. 1979. Transformation of cover-abundance values and its effects on community similarity, Vegetatio39:97-114.

Daniel Gamachu, 1997. Aspects of Climate and Water Budget in Ethiopia. Addis Ababa University Press, Addis Ababa, Ethiopia.

Ensermu Kelbessa, Sebsebe Demissew, Zerihun Woldu and Edwards, S., 1992. Some threatened endemic plants of Ethiopia. In: Sue Edwards and Zemede Asfaw (eds.). The Status of Some Plant Resources in Parts of Tropical Africa. *Botany 2000: East and Central Africa. NAPRECA Monograph Series No. 2.* Published by NAPRECA, Addis Ababa University, and Addis Ababa.

Environment Protection Authority (EPA). (1997). National Conservation Strategy of Ethiopia (Vol I-IV). Addis Ababa.

FAO 1986. Highlands Reclamation Study Ethiopia Final Report, Vol. I & II. Rome, Italy

Friis, I., 1992. Forests and Forest Trees of Northeast Tropical Africa: Their Natural Habitats and Distribution Patterns in Ethiopia, Djibouti and Somalia. *Kew Bull. Add. Ser.* 15:1-396.

Hedberg, I. & Edwards, S. (eds.), 1989. Pittosporaceae to Araliaceae. Flora of Ethiopia and Eritrea Volume 3: 1-460. Addis Ababa, Ethiopia and Uppsala, Sweden.

Hedberg, I., Sebsebe Demissew and Edwards, S. (eds.). (1997). Hydrocharitaceae to Arecaceae. Flora of Ethiopia and Eritrea Volume 6: 1-586. Addis Ababa, Ethiopia and Uppsala, Sweden.

IUCN, 2005. The Red List of Endemic trees and shrubs of Ethiopia and Eritrea, Jose Juis Vivero, Ensermu Kelbessa and sebsebe Demissew, Gorgina Magin and Sara Oldfield (eds), Fauna and Flora Red List International.

Keyzer, M.A. & B. G. J. S. Sonneveld, 2001. The Effect of Soil Degradation on Agricultural Productivity in Ethiopia: a Non-Paragmatic Regional Analysis In Economic Policy Reforms & Sustainable Land Use in LDC's. (Heerink, H. Van Keuken & M. Kurpios - Eds.) Physica Verlag pp 269-292.

Mesfin Bayou and Getachew Tesfaye, Biodiversity assessment in wetland, Northwestern Ethipia, Proceedings of the a National workshop of the Biological Society of Ethiopia, Wetlands and acquatic resources of Ethiopia, challenges and prospects, February 12-13, 2003, Addis Ababa, Ethiopia.

Ministry of Finance and Economic Development (MOFED), 2005. Ethiopia: Building on Progress: A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10). Addis Ababa.

Phillips, S., 1995. Poaceae. Flora of Ethiopia and Eritrea Volume 7: 1-420. Addis Ababa, Ethiopia and Uppsala, Sweden.

Ratry, J.M. 1960. The grass cover of Africa, FAO, Agricultural Stud. Rome.

Pichi-Sermolli, R. C. E., 1957. Una Carta Geobotanica, dell'Africa Orientale Ethiopia and Somalia-Webbia 13: 15-132.

Selome Mekonnen, 2006, Assessment of temporal hydrological variation due to land use changes using remote sensing/GIS: A case study of Lake Tana Basin. KTH

Seleshi Bekele ,Aster Denekew ,Makonnen Loulseged, Willibald Loiskandl Mekonnen Ayana, Tena Alamirew, 2007. Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123)

Sue Edwards 2000. Feasibility Study of Beles Hydropoer Project, Environmental Impact Assessment.

Sutcliffe, J.P. 1993. Economic Assessment of Land Degradation in the Ethiopia Highlands. Addis Ababa, Natural Conservation Strategy Secretariat Ministry of Planning and Economic Development.

Sutcliffe, J.P. 2006. The National biomass Planning in Ethiopia, The Woody Biomass Project, Recommend, 3:4, 1-4.

White F. 1983. The vegetation of Africa, a descriptive memoir to accompany the UNECO/AETFAT/UNSO Vegetation map of Africa, 7 Place de Fontenoy, 75700, Paris.

Williams, J, G and Arlott, N. A., 1992. Field Guide to the Birds of East Africa. Collins, Grafton Street, London.

Woldegabriel G/kidan and Solomon Teka, 2006. Ecological significance, threats and management options of Lake Tana Wetlands: Part 1. Analysis of the biophysical and cultural resources and socio-economic factors, Amhara National regional State environmental Protection Land Adminstration And use Authority, Bahir Dar.

Wudneh T. 1998. Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia, Ph.D Thesis. Wageningen, Wageningen Agricultural University. 150 p.

Zerihun Woldu., 1999. Forests in the vegetation types of Ethiopia and their status in the geographical context. In: S. Edwards, Abebe Demissie, Taye Bekele and G. Haase (eds.). Forest Genetic Resource Conservation: Principles, Strategies and Actions; Proceedings of the National Forest Genetic Resources Conservation Strategy Development Workshop, 21-22 June 1999; Institute of Biodiversity Conservation and Research (IBCR) and the German Technical Co-operation (GTZ); Addis Ababa, Ethiopia.

Appendices

Appendix 3.1. Species, families and categories of plants found in the LTSB

	Species name	Family	Category	Endemicty	IUCN Category
1	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	Tree	NE	LC
2	*Acacia albida* Delile	Fabaceae	Tree	NE	LC
3	*Acacia brevispica* Harms	Fabaceae	Scrambler	NE	LC
4	*Acacia hockii* De Willd.	Fabaceae	Shrub	NE	LC
5	*Acacia seyal* Del. var. seyal Delile	Fabaceae	Tree	NE	LC
6	*Acanthus arboreus* Forssk. var. ruber Engl.	Acanthaceae	shrub	NE	LC
7	*Acanthus polystachyus* Delile	Acanthaceae	Shrub	NE	LC
8	*Acanthus senni* Chiov.	Acanthaceae	Shrub	E	NT
9	*Achyranthes aspera* L.	Amaranthaceae	Herb	NE	LC
10	*Acokanthera schimperi* (A. DC.) Schweinf	Apocynaceae	Shrub	NE	LC
11	*Aeschynomene schimperi* Hochst. Ex A. Rich.	Fabaceae	Herb	NE	LC
12	*Ageratum conyzoides* L.	Asteraceae	Herb	NE	LC
13	*Albizia gummifera* (J.F. Gmel.) C.A.Sm.	Fabaceae	Tree	NE	LC
14	*Albizia malacophylla* (A.Rich.) Walp.	Fabaceae	Tree	NE	LC
15	*Albizia schimperiana* Oliv.	Fabaceae	Tree	NE	LC
16	*Alisma plantago-aquatica* L.	Alismataceae	Herb	NE	LC
17	*Allophylus abyssinicus* (Hochst.)	Sapindaceae	Tree	NE	LC
18	*Aloe trigonantha* Christian	Asphodelaceae	Herb	NE	LC
19	*Amaranthus caudatus* L.	Amaranthaceae	Herb	NE	LC
20	*Amaranthus hybridus* L.	Amaranthaceae	Herb	NE	LC
21	*Amaranthus spinosus* L.	Amaranthaceae	Herb	NE	LC
22	*Amorphophallus abyssinicus* (A. Rich.) NE. Br.	Araliaceae	Herb	NE	LC
23	*Anagallis serpensis Hochst. ex DC*	Scrophularaceae	Herb	NE	LC
24	*Andropogon* abyssinicus L.	Poaceae	Grass	NE	LC
25	*Apodytes dimidiata Arn.*	Icacinaceae	Tree	NE	LC
26	*Asparagus racemosus* Willd.	Asparagaceae	Herb	NE	LC
27	*Bersama abyssinica* Fresen.	Melinthaceae	Tree	NE	LC
28	*Bidens pillosa* L.	Asteraceae	Herb	NE	LC
29	*Bracharia brizantha* (A. Rich.).Stapf	Poaceae	Grass	NE	LC
30	*Bracharia eruciformis* (J.E. Smith) Griseb.	Poaceae	Grass	NE	LC
31	*Bracharia jubuta* (Fig. & De Not.) Stapf	Poaceae	Grass	NE	LC
32	*Bracharia scalaris* Pilg.	Poaceae	Grass	NE	LC
33	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	Tree	NE	LC
34	*Buddleja polystachya* Fresen.	Loganiaceae	Tree	NE	LC
35	*Calotropis procera* (Ait.) Ait.f.	Apocynaceae	Shrub	NE	LC

	Species name	Family	Category	Endemicty	IUCN Category
36	*Calpurnea aurea (Ait.) Benth.*	Fabaceae	Shrub	NE	LC
37	*Carex peregrine* Link	Cyperaceae	Herb	NE	LC
38	*Carissa spinarum* L.	Apocynaceae	shrub	NE	LC
39	*Cassia petersiana* Bolle in Peters	Fabaceae	Shrub	NE	LC
40	*Cayratia gracilis* (Guill. & Perr) Suesseng	Vitaceae	Herb	NE	LC
41	*Celosia trigyna* L	Amaranthaceae	Herb	NE	LC
42	*Celtis africana* Burm. f	Ulmaceae	Tree	NE	LC
43	*Centella asiatica* (Linn.) Urb.	Apiaceae	Herb	NE	LC
44	*Centrostachys aquatica* (R.Br.) Wall. Ex Moq.	Amaranthaceae	Herb	NE	LC
45	*Chionanthus mildbraedii* (Gilg. &	Oleaceae	Tree	NE	LC
46	*Chloris gayana* Kunth	Poaceae	Grass	NE	LC
47	*Citrus auranteus* L.	Rutaceae	Shrub	NE	LC
48	*Clausena anisata* (Willd.) Benth.	Rutaceae	Shrub	NE	LC
49	*Clematis simensis* Fres.	Ranunculaceae	Climber	NE	LC
50	*Clerodendrum myricoides (*Hochst.)	Lamiaceae	Shrub	NE	LC
51	*Clutia abyssinica* Jaub. & Spach.	Euphorbiaceae	Shrub	NE	LC
52	*Coccinia grandis* (L) Voigt	Cucurbitaceae	Herb	NE	LC
53	*Coffea arabica* L.	Rubiaceae	Tree	NE	LC
54	*Combretum collinum* Fresen.	Combretaceae	Tree	NE	LC
55	*Combretum molle* R. Br. ex G. Don	Combteraceae	Tree	NE	LC
56	*Commelina benghalensis* L	Commelinaceae	Herb	NE	LC
57	*Commiphora africana* (A. Rich.) Engl.	Burseraceae	shrub	NE	LC
58	*Cordia africana* Lam.	Boraginaceae	Tree	NE	LC
59	*Crinum abyssinicum* A. Rich.	Amaryllidaceae	Herb	NE	LC
60	*Crotalaria spinosa* Hochst. Ex Benth.	Fabaceae	Herb	NE	LC
61	*Croton macrostachyus* Del.	Euphorbiaceae	Tree	NE	LC
62	*Cynodon dactylon* (L) Pers.	Poaceae	Grass	NE	LC
63	*Cyperus atronervatus* Bock.	Cyperaceae	Herb	E	LC
64	*Cyperus bulbosus* Vahl	Cyperaceae	Herb	NE	VU
65	*Cyperus dereilema* Steud.	Cyperaceae	Herb	NE	LC
66	*Cyperus digitatus* Roxb.	Cyperaceae	Herb	NE	LC
67	*Cyperus distans* L.f.	Cyperaceae	Herb	NE	LC
68	*Cyperus dives* Del.	Cyperaceae	Herb	NE	LC
69	*Cyperus flavesens* L.	Cyperaceae	Herb	NE	LC
70	*Cyperus latifolius Poir.*	Cyperaceae	Herb	NE	LC
71	*Cyperus munditii* (Nees) Kunth	Cyperaceae	Herb	NE	LC
72	*Cyperus nitidus* Lam.	Cyperaceae	Herb	NE	LC
73	*Cyperus papyrus L.*	Cyperaceae	Herb	NE	LC
74	*Cyperus rotundus* L.	Cyperaceae	Herb	NE	LC
76	*Cyperus sanguinolentus* Vahl	Cyperaceae	Herb	NE	LC
77	*Cyperus schimperianus* Steud.	Cyperaceae	Herb	NE	LC
78	*Datura stramonium* (Hoc]1st. Ex A. Rich.)Stapf	Solanaceae	Herb	NE	LC

	Species name	Family	Category	Endemicty	IUCN Category
79	*Dichrostachys cinerea* L.	Fabaceae	Shrub	NE	LC
80	*Digitaria abyssinica* (A. Rich.) Stapf	Poaceae	Grass	NE	LC
81	*Digitaria velutina* (Forssk.) P. Beauv.	Poaceae	Grass	NE	LC
82	*Dinebera retroflexa* (Vahl) Panzer	Poaceae	Grass	NE	LC
83	*Diospyros abyssinica* (Hiern) P. White	Ebenaceae	Tree	NE	LC
84	*Diospyros mespiliformis* A. DC.	Ebenaceae	Tree	NE	LC
85	*Dodonaea angustifolia* L.f.	Sapindaceae	Shrub	NE	LC
86	*Dombeya torrida* (J.F. Gmel.) Bamps	Sterculaceae	Tree	NE	LC
87	*Dovyalis abyssinica* (A. Rich.) Warb.	Flacourtiaceae	Shrub	NE	LC
88	*Dracaena steudneri* Engl.	Dracaenaceae	Tree	NE	LC
89	*Dyschoriste radicans* Hochst.	Acanthaceae	Herb	NE	LC
90	*Echinochloa colona* (L.) Link	Poaceae	Grass	NE	LC
91	*Echinochloa haploclada* (Stapf) Stapf	Poaceae	Grass	NE	LC
92	*Echinochloa stagnina* (Retz.) P. Beauv. Eckl. & Zeyh.	Poaceae	Grass	NE	LC
93	*Ehretia cymosa* Thonn	Boraginaceae	Tree	NE	LC
94	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae	Grass	NE	LC
95	*Embelia schimpri* Vatke	Myrsinaceae	Shrub	NE	LC
96	*Emilia abyssinica (L.) Vahl*	Asteraceae	Herb	NE	LC
97	*Ensete ventricosum (Welw.)* Cheesman	Musaceae	Herb	NE	LC
98	*Eriochloa nubica* (Steud.) Thell	Poaceae	Grass	NE	LC
99	*Erythrina abyssinica* Lam. ex DC.	Fabaceae	Tree	NE	LC
100	*Erythrina brucei* Schweinf	Fabaceae	Tree	E	LC
101	*Eucalvptus* camaldulensis Dehnh	Myrtaceae	Tree	NE	LC
102	*Eucalyptus globulus* Labill.	Myrtaceae	Tree	NE	LC
103	*Euclea racemosa subsp. schimperi* (A. DC.) P. White	Ebenaceae	Shrub	NE	LC
104	*Eulophia spp.*	Orchidaceae	Orchid	NE	LC
105	*Euphorbia ampliphylla* Pax	Euphorbiaceae	Tree	NE	LC
106	*Euphorbia tirucalli* L.	Euphorbiaceae	Tree	NE	LC
107	*Ficus ovata* Vahl	Moraceae	Tree	NE	LC
108	*Ficus sur* Forssk.	Moraceae	Tree	NE	LC
109	*Ficus sycomorus* L.	Moraceae	Tree	NE	LC
110	*Ficus thonningii* Blume	Moraceae	Tree	NE	LC
111	*Ficus vasta* Forssk.	Moraceae	Tree	NE	LC
112	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	Herb	NE	LC
113	*Flacourtia indica* (Burm. f) Merrill	Flacourtiaceae	Shrub	NE	LC
114	*Fluggea virosa* (Willd.) Voigt.	Euphorbiaceae	Shrub	NE	LC
115	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	Shrub	NE	LC
116	*Gardenia volkensii* K. Schum	Rubiaceae	Shrub	NE	LC
117	*Girardinia bulosa* (Steud.) Engl.	Urticaceae	Herb	NE	LC
118	*Grewia bicolor* Juss.	Tiliaceae	Shrub	NE	LC
119	*Grewia vilosa* WilId.	Tiliaceae	Shrub	NE	LC
120	*Guzotia scabra (Vis.)* Chiov	Asteraceae	Herb	NE	LC
121	*Hagenia abyssinica* (Bruce) J.F. Gmel.	Rosaceae	Tree	NE	LC
122	*Harpachne schimperi Hochst.* ex A. Rich.	Poaceae	Grass	NE	LC
123	*Heteromorpha trifoliata* (Wendl.)	Apiaceae	Shrub	NE	LC

	Species name	Family	Category	Endemicty	IUCN Category
124	*Hibiscus cannabinus* L.	Malvaceae	Herb	NE	LC
125	*Hibiscus macranthus* Hochst. ex A. Rich.	Malvaceae	Herb	NE	LC
126	*Hydrocharis haesas* L.	Hydrocharitaceae	Herb	NE	LC
127	*Hygrophila schulii*(Schum.) Almeida & Almeida	Acanthaceae	Herb	NE	LC
128	*Hyparrhenia antihisroides* (Hochst. ex A rich.)	Poaceae	Grass	NE	LC
129	*Hyparrhenia hirta* (L) Stapf.	Poaceae	Grass	NE	LC
130	*Hyparrhenia ruffa* (Nees) Stapf.	Poaceae	Grass	NE	LC
131	*Hypericum revolutum* Vahl	Hypericaceae	Shrub	NE	LC
132	*Hypoestes forskalii* (Vahl.) R. Br.	Acanthaceae	Herb	NE	LC
133	*Ipomoea aquatica Forssk.*	Convolvulaceae	Herb	NE	LC
134	*Ipomoea tricolor Cav.*	Convolvulaceae	Strangler	NE	LC
135	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	Tree	NE	LC
136	*Justicia flava (Forssk.)* Vahl	Acanthaceae	Herb	NE	LC
137	*Justicia ladanoides* Lam.	Acanthaceae	Shrub	NE	LC
138	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Herb	NE	LC
139	*Lagarosiphon cordofanus* Casp.	Hydrocharitaceae	Herb	NE	LC
140	*Lagarosiphon steudneri* Casp.	Hydrocharitaceae	Herb	NE	LC
141	*Lagenaria siceraria* (Molina) Stand.	Cucurbitaceae	Herb	NE	LC
142	*Lantana camara* L.	Verbenaceae	Shrub	NE	LC
143	*Lepidotrochilia volkensii* (Guerke)	Meliaceae	Tree	NE	LC
144	*Leucas martinicensis (*Jacq.) R.Br	Lamiaceae	Herb	NE	LC
145	*Maesa lanceolata* Forssk.	Anacardiaceae	Tree	NE	LC
146	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	Shrub	NE	LC
147	*Maytenus obscura* (A.Rich.) Cufod.	Celastraceae	Shrub	NE	LC
148	*Maytenus serrata* (Thunb.)	Celastraceae	Shrub	E	LC
149	*Medicago polymorpha* L.	Poaceae	Herb	NE	LC
150	*Melinus repens* (Willd.) Zizka	Poaceae	Grass	NE	LC
151	*Microchloa kunthii* Desv.	Poaceae	Tree	NE	LC
152	*Millettia ferruginea* (Hochst.) Bak	Fabaceae	Tree	E	LC
153	*Mimusops kummel* A. DC.	Sapotaceae	Tree	NE	LC
154	*Myrsine africana L.*	Myrsinaceae	Shrub	NE	LC
155	*Nuxia congesta* R. Br. ex Fresen.	Loganiaceae	Tree	NE	LC
156	*Nymphaea caerulea* Savizny	Nymphaceae	Herb	NE	LC
157	*Ocimum lamiifolium* Hochst. ex Benth.	Lamiaceae	Herb	NE	LC
158	*Olea europaea* subsp. cuspidata (Wall. ex. DC) Cifferri	Oleaceae	Tree	NE	LC
159	*Olinia rochetiana* Juss.	Olinaceae	tree	NE	LC
160	*Oplismenus* compositus (Retz.) P. Beauv.	Poaceae	Grass	NE	LC
161	*Opuntia ficus-indica* (L.) Mill.	Cactaceae	Succulent shrub	NE	LC
162	*Oryza longistaminatata* A. Cheval. & Roehr.	Poaceae	Grass	NE	LC
163	*Osyris quadripartita* Salzm. ex Decne.	Santalaceae	Shrub	NE	LC
164	*Otostegia integriflia* Benth.	Lamiaceae	Shrub	NE	LC
165	*Ottelia ulvifolia* (Planch.) Walp.	Hydrocharitaceae	Herb	NE	LC
166	*Oxyanthus speciosus* DC.	Rubiaceae	Shrub	NE	LC
167	*Panicum coloratum* L.	Poaceae	Grass	NE	LC

	Species name	Family	Category	Endemicty	IUCN Category
168	*Pavetta. abyssinica* Fresen.	Rubiaceae	Shrub	NE	LC
170	*Pennisetum mezianun* Leeke	Poaceae	Grass	NE	LC
171	*Pennisetum thunbergii* Kunth	Poaceae	Grass	NE	LC
172	*Persicaria glabra* (Willd.) Gomez de la Maza	Polygonaceae	Herb	NE	LC
173	*Persicaria senegalensis* (Meisn.) Sojak	Polygonaceae	Herb	NE	LC
174	*Persicaria setulosa* (A. Rich.). K.L.	Polygonaceae	Herb	NE	LC
175	*Phoenix reclinata* Jacq.	Palmaceae	Tree	NE	LC
176	*Physalis peruviana* L.	Solanaceae	Herb	NE	LC
177	Phytolacca dodecandra L' Herit	Phytolaccaceae	Shrub	NE	LC
178	*Pistia statiotes L.*	Araceae	Floating herb	NE	LC
179	*Pittosporum viridiflorum* Sims	pittosporaceae	Tree	NE	LC
180	*Plantago lanceolata* L.	Plantaginaceae	Herb	NE	LC
181	*Podocarpus falcatus* Thunb. R. Br. ex Mirb.	Podocarpaceae	Tree	NE	LC
182	*Potamogeton schweinfurthii* A. Benn.	Potamogetonaceae	Herb	NE	LC
183	*Potamogeton thunbergii* Cham. & Schlecht.	Potamogetonaceae	Herb	NE	LC
184	*Premna schimperi* Engl.	Lamiaceae	Shrub	NE	LC
185	*Prunus africana* Hook. f. Kalkm.	Rosaceae	Tree	NE	LC
186	*Rhamnus staddo* A. Rich.	Rhamnaceae	Shrub	NE	LC
187	*Ranunculus volkensii* Engl.	Ranunculaceae	Herb	NE	LC
188	*Rhus glutinosa* A. Rich.	Anacardiaceae	Shrub	NE	LC
189	*Rhus retinorrhea* Steud ex Oliv.	Anacardiaceae	Shrub	NE	LC
190	*Rhynchosia totta* (Thunb.) DC.	Fabaceae	Herb	NE	LC
191	*Ricinus communis* L.	Euphorbiaceae	Tree	NE	LC
192	*Rosa abyssinica* R. Br. ex Lindl	Rosaceae	Shrub	NE	LC
193	*Ritchiea albersii Gilg.*	Capparidaceae	Herb	NE	LC
194	*Rothmannia urcelliformis* (Hiern) Robyns	Rubiaceae	Tree	NE	LC
195	*Rumex abyssinicus* Jacq.	Polygonaceae	Herb	NE	LC
196	*Rumex nepalensis* Spreng.	Polygonaceae	Herb	NE	LC
197	*Rumex nervosus* Vahl.	Polygonaceae	Shrub	NE	LC
198	*Ruttya speciosa (Hochst.) Engl.*	Acanthaceae	Shrub	E	VU
199	*Salix subserrata* Willd.	Salicaceae	Tree	NE	LC
200	*Sapium ellipticum* (Hochst.) Pax (Schellenb.) Stearn	Euphorbiaceae	Tree	NE	LC
201	*Schefflera abyssinica* A. Rich.	Araliaceae	Tree	NE	LC
202	*Schoenoplectus sp.*	Cyperaceae	Herb	NE	LC
203	*Scolopia theifolia* Gilg,	Flacourtiaceae	Shrub	NE	LC
204	*Senna didymobotrya* Fresen.	Fabaceae	Shrub	NE	LC
205	*Senna occidentalis* (L.) Link	Fabaceae	Shrub	NE	LC
206	*Senna petersiana* (Bolle) Lock	Fabaceae	Shrub	NE	LC
207	*Senna singueana* (Del.) Lock	Fabaceae	Shrub	NE	LC
208	*Sesbania sesban* (L.) Merr.	Fabaceae	Shrub	NE	LC
209	*Setaria atrata* Hack.	Poaceae	Shrub	NE	LC
210	*Setaria incrasata* (Hochst.) Hack.	Poaceae	Grass	NE	LC
211	*Setaria pumila* (Poir.) & Roem. & Schult.	Poaceae	Grass	NE	LC
212	*Sicyos polyacanthus* Cogn.	Cucurbitaceae	Herb	NE	LC
213	*Sida schimperiana* Hochst. Ex. A. Rich.	Malvaceae	Herb	NE	LC
214	*Sideroxylon oxanthus* Hutch. & Bruce	Sapotaceae	Shrub	E	NT

	Species name	Family	Category	Endemicty	IUCN Category
215	*Snowdenia polystachya* (Fresen.) Pilg	Poaceae	Grass	NE	LC
216	*Solanum giganteum* Jacq.	Solanaceae	Shrub	NE	LC
217	*Solanum marginatum* L.f.	Solanaceae	Herb	E	LC
218	*Solanum nigrum* L.	Solanaceae	Herb	NE	LC
219	*Sorghum verticilliflorum* (Steud.) Stapf	Poaceae	Grass	NE	LC
220	*Spirodella polyrrhiza* (L.) Schleiden	Lemnaceae	Herb	NE	LC
221	*Sphaeranthus suaveolens (*Forrsk.). DC.	Asteraceae	Herb	NE	LC
222	*Stereospermum kunthianum* Cham.	Bignoniaceae	Tree	NE	LC
223	*Syzygium guineense* (Willd.) DC.	Myrtaceae	Tree	NE	LC
224	*Tagetus minuta* L.	Asteraceae	Herb	NE	LC
225	*Tapinanthus globiferus* (A Rich) Tieghem	Loranthaceae	Epiphyte	NE	LC
226	*Teclea nobilis* Del.	Rutaceae	Tree	NE	LC
227	*Terminalia brownii* Fresen.	Combretaceae	Tree	NE	LC
228	*Tephrosia pumila* (Lam.) Pers.	Fabaceae	Herb	NE	LC
229	*Trifolium quartinianum* A. Rich.	Fabaceae	Herb	NE	LC
230	*Trifolium rueppellianum* Fresen.	Fabaceae	Herb	NE	LC
231	*Triumfetta annua* L.	Tiliaceae	Herb	NE	LC
232	*Turraea holstii* Guerke	Meliaceae	Tree	NE	LC
233	*Typha domingensis* Pers.	Typhaceae	Herb	NE	LC
234	*Urera hypselodendron* (A. Rich.) Wedd.	Urticaceae	Liana	NE	LC
235	*Vepris dainellii* (Pich.-Serm.) kokwaro	Rutaceae	Tree	E	LC
236	*Verbena officinalis* L.	Verbenaceae	Shrub	NE	LC
237	*Vernonia amygdalina* Del.	Asteraceae	Tree	NE	LC
238	*Vernonia leopoldii* Sch.Bip	Asteraceae	Shrub	E	LC
239	*Vernonia auriculifolia* Hiern.V. sp.	Asteraceae	Shrub	NE	LC
240	*Vigna luteola* (Jacq.) Benth.	Fabaceae	Herb	NE	LC
241	*Vigna vexillata* (L.) A. Rich.	Fabaceae	Herb	NE	LC
242	*Xanthium strumarium* L.	Asteraceae	Herb	NE	LC
243	*Ximenia americana* L.	Olacaceae	Shrub	NE	LC
244	*Zannichellia pailistris* L.	Zannichelliaceae	Herb	NE	LC

NT = not threatened
VU = Vulnerable
LC = Least concern

Appendix 3.2. Average cover abundance values of species of plants encountered in the sample plots in LTSB

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Acacia abyssinica					1		5													
Acacia albida								10												
Acacia brevispica				1																
Acacia hockii				1																
Acacia seyal var. seyal					1															
Acanthus arboreus										5	1									
Acanthus polystachyus																			1	
Acanthus senni Chiov.	5					5													5	
Achyranthes aspera	5																		1	
Aeschynomene schimperi										5									5	
Ageratum conizoides	10									5									5	
Akokanthera schimperi						5							1		1		1			
Albizia gummifera	2												1							
Albizia malacophylla		10		1																
Albizia schimperiana	5			1		20	1		5				1				10			
Alisma plantago-aquatica															1					
Allophylus abyssinicus						5														
Aloe trigonantha										5										
Amaranthus caudatus																			1	
Amaranthus hybridus																			5	
Amaranthus spinosus.																			1	
Amorphophallus abyssinicus															5					
Anagallis serpens																		1	5	
Andropogon abyssinicus																			5	
Apodytes dimidiata	1					1							1		1		5			
Asparagus racemosus	1														5					
Bersama abyssinica .	5														1		5			

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Bidens pillosa															10				5	
Bracharia brizantha																			1	
Bracharia eruciformis																			5	
Bracharia jubuta																			5	
Bracharia scalaris																			5	
Bridelia micrantha															1					
Buddleja polystachya																	10			
Calotropis procera									10											
Calpurnea aurea	10			10		10	5		1			10	5		5		1			
Carex peregrine																			1	
Carissa spinarum	5	5		5		5							1		5		10			
Cassia Petersiana	5														1					
Cayratia gracilis																			1	
Celosia trigyna																			5	
Celtis Africana	10												10				5			
Centella asiatica														5						
Centrostachys aquatica																			5	
Chionanthus mildbraedii															1					
Chloris gayana										5										
Citrus auranteus	5																			
Clausena annisata.	5					5											5			
Clematis simensis											1				5		5			
Clerodendrum myricoides						1				1										
Clutia abyssinica.						10														
Coccinia grandis																			5	
coffea Arabica	30					5							5							
Combretum collinum											5									
Combretum molle											5									
Commiphora africana		1													1					
Commelina benghalensis																			1	
Cordia africana	5							20				10	10		1		5			
Crinum abyssinicum															5					
Crotalaria spinosa																			1	
Croton macrostachyus	10							10				10			1		1			

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Cynodon dactylon			20											5				10	10	10
Cyperus atronervatus																			5	
Cyperus bulbosus																			5	
Cyperus dereilema																			5	
Cyperus digitatus																			1	
Cyperus distans																			5	
Cyperus dives Del.																5		5		
Cyperus flavesens																			1	
Cyperus latifolius			5							5						5			5	
Cyperus munditii																			1	
Cyperus nitidus																			5	
Cyperus papyrus														5		10		10	10	
Cyperus rotundus																			1	
Cyperus sanguinolentus																			1	
Cyperus schimperianus																			1	
Datura stramonium																			1	
Dichrostachys cinerea											5									
Digitaria abvssinica																			5	
Digitaria velutina																			5	
Dinebera retroflexa																			1	
Diospyros abyssinica											5									
Diospyros mespiliformis	5												10		10					
Dodonea angustifolia							5				5				1		5			
Dombeya torrida															5		1			
Dovyalis abyssinica						1														
Dracaena steudneri							1								5					
Dyschoriste radicans																			5	
Echinochloa colona																			5	
Echinochloa haploclada																			5	
Echinochloa stagnina			20		5									10		5			1	
Ehretia cymosa	10															10	5			
Eleusine floccifolia			5																1	
Embelia schimpri						5														
Emilia abyssinica																			1	
Ensete ventricosum															1					

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Eriochloa nubica										5				10						
Erythrina abyssinaca	5								5		5	5	5						5	
Erythrina brucei															5				5	
Eucalyptus camaldulensis	5																			
Eucalyptus globulus	5																			
Euclea racemosa subsp. schimperi															1		5			
Eulophia spp.															1					
Euphorbia ampliphylla						5											5			
Euphorbia tirucalli									5											
Ficus ovata															5		1			
Ficus sur	10																			
Ficus sycomorus															5		1			
Ficus thonningii															10		1			
Ficus vasta.	10				5			10			5		5							
Fimbristylis dichotoma																			1	
Flacourtia indica											5									
Fluggea virosa											5									
Galineria saxifraga						5														
Gardenia volkensii		1									1									
Gerardinia bulbosa	10																		5	
Grewia bicolor											1									
Grewia vilosa							1				1									
Guzoita scabra										1									1	
Hagenia abyssinica						1														
Harpachne schimperi										5										
Heteromorpha trifoliata											1									
Hibiscus cannabinus																			1	
Hibiscus macranthus																			1	
Hyparrhenia antihisroides										5	20									
Hydrocharis haesas																			5	
Hygrophila auriculata			5							20				5				10	10	
Hyparrhenia hirta					10						5						5			
Hyparrhenia rufa										5									1	
Hypericum revolutum						1			1											

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Hypoestes forskalii						20														
Ipomoea aquatic			20											10		10		5	5	
Ipomoea tricolor						5														
Juniperus procera						5											1			
Justicia flava																			5	
Justicia ladanoides						5														
Justisia schimperiana	5					10					5				1				5	
Lagarosiphon cordofanus																1			1	
Lagarosiphon steudneri													1			5				
Lagenaria siceraria																			1	
Lantana camara											5									
Lepidotrochilia volkensii	5																			
Leucas martinicensis																			1	
Maesa lanceolata				5	5															
Maytenus arbutifolia	5										5				5		5			
Maytenus obscura																	5			
Maytenus serrata	5					5			5	1	1	5					5			
Medicago polymorpha																			1	
Melinnus repens					5					5										
Microchloa kunthii																			1	
Millettia ferruginea	20					10							20		10		5			
Mimusops kummel													10		1					
Myrsine Africana						1											1			
Nuxia congesta						1	5													
Nymphaea caerulea					5									1		1			1	
Ocimum lamiifolium																			1	
Olea europaea subsp. cuspidata	5					10			1						5		5			
Olinia rochetifolia	5																			
Oplismenus compositus																			1	
Opuntia ficus-indica						5														
Oryza longistaminatata			5							10										
Osyris quadripartita						1														
Otostegia integrifolia									5											
Ottelia ulvifolia																1			1	
Oxyanthus speciosus															1					

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Panicum coloratum																			1	
Pavetta. abyssinica		5																		
Pennisetum mezianun					10														5	5
Pennisetum thunbergii																			1	
Persicaria glabra																		5	5	5
Persicaria senegalensis																			1	
Persicaria setulosa																5				
Phoenix reclinata															2					
Physalis peruviana																			1	
Phytolaca dodecandra						1							1							
Pistia statiotes					5															1
Pittosporum viridiflorum	5																			
Plantago lanceolata																			1	
Podocarpus falcatus															1					
Potamogeton schweinfurthii																1		1		
Potamogeton thunbergii																1		1		
Premna schimperi						5														
Prunus africana	10					5														
Ptereolobium stellatum				10					5						1					
Ranunculus volkensii																			1	
Rhamnus prinoides															5					
Rhamnus stado		5				1														
Rhus glutinosa A. Rich.		5													1					
Rhus retinorrhea		1																		
Rhynchosia totta																			1	
Ricinus communis																			5	
Rosa abyssinica						1														
Ritchiea albersii						1														
Rothmania urcelliformis	5																			
Rumex abyssinicus																			1	
Rumex nepalensis																			5	
Rumex nervosus									10											
Ruttya speciosa	5	2				5							2							
Salix subserrata																				
Sapium ellipticum	10												5		5					5

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Scheflera abyssinica						5														
Schoenoplectus																2				
Scolopia theifolia						5														
Senna didymobotrya						1														
Senna occidentalis															1					
Senna singueana				5							5	5			5					
Senna petersiana	5																			
Sesbania sesban										10										
Setaria atrata										1									5	
Setaria incrasata										1			1						1	
Setaria pumila													5						1	
Sicyos polyacanthus.																			1	
Sida schimperiana																			1	
Sideoxylon gillettii						5														
Syzygium guineense	5				5										1		5			5
Snowdenia polystachya																			1	
Solanum marginatum	5																		1	
Solanum nigrum																			1	
Solanum gigantium						1														
Sorghum verticilliflorum											5									
Spirodella polyrrhiza																1		1		
Sphaeranthus suaveolens																		1	5	
Streospermum kuntianum.		1					1		1			1								
Tagetus minuta																			1	
Tapinanthus globiferus											1									
Teclea nobilis.	5	1				5									1					
Terminalia brownie						1														
Tephrosia pumila																			1	
Trifolium quartinianum																			1	
Trifolium rueppellianum																			1	
Triumfetta annua																			1	
Turraea holstii															1					
Typha domingensis														10		10		10		
Urera hypselodendron						5												1		
V allisneria spiralis forma aethiopica																5		5		

Plant Species	Zege forest	Zege Ararat	Zege wetland	Wegelsa	Enfranz Wenz	Tera Gedam	Lebo kemkem	Guzara	Maksegnit	Gorgora Wawa	Gorgora Hill	Enfranz Hill	Deq Island	Deq wetland	Along Nile	Gerima Wetland	Kunzila Forest	KunziLA Wetland	plain	Hamusit River
Vepris dainellii	5																			
Verbena ojficinalis																				
Vernonia amygdalina.	10																			
Vernonia auriculifolia.	10			10																
Vernonia leopoldii						5														
Vigna luteola.																			1	
Vigna vexillata																			1	
Xanthium strumarium										5									5	
Ximenia americana											1									
Zannichellia pailistris																			1	

Appendix 3. 3. Species, families and life-forms of crop plants encountered in LTSB during the period of the study

Species	**Family**	**Lifeform**
Allium cepa L.	Alliaceae	Annual
Allium sativum L.	Alliaceae	Annual
Brassica napus L.	Brassicaceae	Annual
Brassica carinata A. Braun	Brassicaceae	Annual
Capsicum frutescens L.	Solanaceae	Annual
Carica papaya L.	Caricaceae	Perennial
Carthamus tinctorius L.,	Asteraceae	Annual
Citrus auratifolia Christm.	Rubiaceae	Perennial
Coffea arabica L.	Rubiaceae	Perennial
Eleusine coracana (L.) Gaertn.	Poaceae	Annual
Eragrostis tef (Zucc.) Trotter.	Poaceae	Annual
Guizotia abyssinica (Linn. f.)	Asteraceae	Annual
Helianthus annus L.	Asteraceae	Annual
Hordeum vulgare L.	Poaceae	Annual
Lathyrus sativus L.	Fabaceae	Annual
Lens culinaris L.	Fabaceae	Annual
Lupinus albus L.	Fabaceae	Annual
Mangifera indica Linn.	Anacardiaceae	Perennial
Musa paradisca L.	Musaceae	Perennial
Nigella sativa L.	Ranunculaceae	Annual
Oryza sativa L.	Poaceae	Annual
Persea americana Mill,	Lauraceae	Perennial
Pisum sativum L.	Fabaceae	Annual
Psidium guajava Linn.	Myrtaceae	Perennial
Rhamnus prinoides L'Herit.	Rhamnaceae	Perennial
Sorghum bicolor (L.) Moench	Poaceae	Annual
Triticum durum L.	Poaceae	Annual
Vicia faba L.	Fabaceae	Annual
Zea mays L.	Poaceae	Annual
Zingiber officinale Roscoe	Zingeberaceae	Perennial

Appendix 3.4 Tree species encountered in Bahirdar

Species	Family
Acacia mearnsii De Wild	Fabaceae
Acacia seyal Del var seyal	Fabaceae
Arudo donax L.	Poaceae
Bersama abyssinica Fresen.	Melianthaceae
Bougainvillea glabra Choisy	Nyctabinaceae
Calpurnea aurea (Ait.) Benth.	Fabaceae
Carica papaya L.	Caricaceae
Carissa spinarum L.	Apocynaceae
Casuarina equisetifolia L.	Casuarinaceae
Citrus aurantium L.	Rutaceae
Coffea arabica L.	Rubiaceae
Cordia africana Lam.	Boraginaceae
Croton macrostachyus Hochst.	Euphorbiaceae
Cupressus lusitanica Mill.	Cupressaceae
Dodonea angustifolia L.f.	Anacaraceae
Dracaena steudneri Schweinf. ex Engl	Dracaenaceae
Eucalyptus camaldulensis Dehnh	Myrtaceae
Euphorbia pulcherima	Euphorbiaceae
Euphorbia tirucalli L.	Euphorbiaceae
Ficus elastica Roxb. ex Hornem	Moraceae
Ficus sycomorus L.	Moraceae
Ficus vasta Forssk.	Moraceae
Grevillea robusta A. Cunningham ex R. Br.	Proteaceae
Hibiscus rosa-sinensis L.	Malvaceae
Jacaranda mimosifolia D. Don	Bignoniaceae
Juniperus procera Hochst. ex Endl.	Cupressaceae
Justicia schimperiana (Hochst. ex Nees) T. Anders.	Acanthaceae
Lantana camara L.f.	Verbenaceae
Leucaena leucocephala (Lam.) De wit	Fabaceae
Mangifera indica L.	Anacaraceae
Melia azadiracta A. Juss.	Meliaceae
Milletia ferruginea (Hochst.) Bak	Fabaceae
Nerium Oleander L.	Apocynaceae
Olea europaea L. subsp. cuspidata (DC) Ciffieri	Oliaceae
Persea americana Mill.	Lauraceae
Phoenix canariensis Chabaud	Palmaceae
Phoenix reclinata Jacq.	Palmaceae
Populus alba L.	Salicaceae
Psidium guajava L.	Myrtaceae
Ptereolobium stellatum (Forssk.) Brenan	Fabaceae
Ricinus communis L.	Euphorbiaceae
Saccharum officinalis L.	Poaceae
Senna didymobotrya Fresen.	Fabaceae
Sesbania sesban (L.) Merr.	Fabaceae

Spathodia nilotica Seem.	Bignoniaceae
Tecoma stans Juss.	Bignoniaceae
Vernonia amygdalina Del.	Astraceae
Washingtonia filifera (Linden ex Andre') H Wendl.	Palmaceae

Appendix 3.5

Environmental Policies and Legislations

I. The Constitution of the FDRE (1995)

The Constitution provides the following basic policies pertaining to natural resources management and the environment:

- Government and all Ethiopian citizens shall have the duty to protect the country's environment and natural resources;
- Design and implementation of development programs and projects shall not damage or destroy the environment;
- People have the right to full consultation and expression of views in the planning and implementation of environment policies and projects that affect them directly.

II Conservation Strategy of Ethiopia (1997)

The major environmental and natural resources management issues that Ethiopia is faced with are well documented in the Conservation Strategy of Ethiopia (FDRE, 1997). The detailed strategies and action plans, as well as the institutional arrangements required for the implementation of sectoral as well as cross-sectoral interventions, for the management of Ethiopia's natural, human-made and cultural resources are contained in the Conservation Strategy of Ethiopia (CSE) documents, which are available in four different volumes. The CSE provides an adequate umbrella strategic framework detailing principles, guidelines and strategies for the effective management of the environment. The CSE deals with eleven sectoral and eleven cross-sectoral issues.

III Environment Policy (1997)

At the Federal level, an approved Environmental Policy is in place. The overall objective of the policy is to promote sustainable social and economic development of the country through the conservation and sustainable utilization of the natural, man-made and cultural resources and environment of the country. It specifies the policy objectives, key guiding principles, sectoral and cross-sectoral policy frameworks and implementation strategies to be followed so that the overall objectives can be realized.

Cross-sectoral policy issues include population growth and environment, community participation and environment, land and natural resource use rights, land use planning, social and gender issues, environmental accounting and economics, environmental information system, environmental research, environmental impact assessment, environmental education and awareness, institutional arrangements, legislation and monitoring. The sectoral policy elements deal with soil conservation and sustainable agriculture, forest resources, biodiversity, water resources, energy, mineral resources, urban environment and environmental health, pollution from industrial waste and hazardous substances, pollution and climate change, and cultural and natural resources.

IV Biodiversity Policy (1998)

The policy provides for guidance towards the effective conservation, rational development and sustainable utilization of the country's biodiversity. In general, the policy consists of comprehensive provisions on the conservation and sustainable utilization of biodiversity.

V Land Policy and Tenure

The Constitution states that the right to ownership of rural and urban land, as well as natural resources, is exclusively vested in the State and the people of Ethiopia. Article 40 of the Constitution states that land is a common property of the nation, nationalities and people of Ethiopia, and shall not be subjected to sale or to any other means of transfer.

VI Investment Policy (Proclamation No. 37/1996)

The investment objectives specified in the proclamation emphasize the maximum exploitation of natural resources without considering options such as rational use, conservation and rehabilitation of threatened natural resources. Maximization of exploitation of natural resources without maintaining the balance of sustainability is detrimental to the natural resources and the intended development itself. On the other hand, the provision in the proclamation that requires impact assessments be carried out for investment projects can be amplified by other laws with a view of addressing the concerns of biodiversity conservation and sustainable utilization of its components.

VII International Conventions

Ethiopia has ratified the following international conventions that are relevant to natural resource/environmental management:

- Convention on Biological Diversity (ratified through Proc. No. 98/94);
- Framework Convention on Climate Change (ratified through Proc. No. 97/1994);
- The Vienna Convention on the Protection of the Ozone Layer and the Montreal Protocol ratified in January 1996;
- The United Nations Conventions to Combat Desertification (ratified through Proc. No. 80/1997); and
- The Convention on International Trade in Endangered Species (CITES) through proclamation No.14/1970.

The government has established an Environmental Protection Authority designated as the focal point for the implementation of the above-cited conventions.

VIII Environmental Impact Assessment Proclamation

The Proclamation was enacted in 2002 (Proc. No. 299/2002). Based on this regulation, the EPA drafted regulations, environmental guidelines and standards to implement and enforce them effectively. Environmental guidelines are among the tools for facilitating the consideration of environmental issues and principles of sustainable development into development proposals. The sequel to enactment of this Proclamation is the preparation of sectoral impact assessment guidelines focusing on agriculture, transport, industry, tannery and settlements.

IX Land Laws (1997)

Land-holding rights provide the right to use land for agricultural purposes as well as to lease, bequeath to family members, acquire property thereon, by labor or capital, and to sell, exchange and bequeath the same. The proclamation also addresses environmental concerns.

X Forestry Laws (1994; Proc. No.94/1994)

The law has incorporated provisions that aim at ensuring the conservation of forests, and determining the system by which forest resources shall be developed and utilized. One of the objectives of the establishment of State Forests is to conserve genetic resources and/or ecosystems. For example, the law prohibits the harvest of *Hagenia abyssinica*, *Cordia africana*, *Podocarpus gracillior*, *Juniperus procera* from either 'state' or 'regional forests'.

XI Wildlife Laws (Proc. No.192/1980; No. 416/1972)

These laws provide for wildlife conservation. Protected Areas exist that are specifically demarcated by law for the protection of wildlife; Conservation Areas include National Parks (for ecological, scientific and aesthetic use), Game Reserves (conserving wildlife), Controlled Hunting Areas (conservation of wildlife) and Sanctuaries (conservation of wildlife). Hunting of wildlife without a permit is prohibited even outside protected areas, except for the immediate defense of human life.

Environmental Institutions

I The Environmental Protection Authority (EPA)

The EPA was established in 1995 (Proc. No. 9/1995) and was re-established in October 2002 under Proclamation 295/2002. The EPA is directly accountable to the Prime Minister. The objective of the EPA is to formulate policies, strategies, laws and standards, which foster social and economic development in a manner that enhances the welfare of people, the safety of the environment, and the sustainability of the project to ensure the effectiveness of the implementation process. Among the powers vested upon it, those pertinent to the present report are to:

- Coordinate measures to ensure the environmental objectives provided under the Constitution and the basic principles set out in the Environmental Policy of Ethiopia are realized;
- Prepare, review and update, or as necessary, cause the preparation of environmental policies, strategies and laws in consultation with the component agencies, other concerned organs and the public at large: upon approval, monitor and enforce their implementation;
- Promote or assist in the formulation of environmental protection action plans and projects and solicit support of such action plans and projects;
- Prepare directives to implement environmental protection laws and upon approval, ensure their implementation.

II Sectoral Environmental Units

The establishment or delegation of an environmental unit for every component agency is provided under the Environmental Protection Organs Establishment Proclamation (Proc. 295/2002).

III Regional Environmental Agencies

Provisions for establishing Regional Environmental Agencies are also included under Proclamation No. 295/2002. The Amhara Environmental Protection, Land Administration and Utilization Authority (EPLAUA), established by Proclamation No. 47/2000, is designated as a Regional Environmental Agency. The main objectives of EPLAUA, which is accountable to the Executive Committee of the Amhara National Region and the President, are to avoid environmental pollution caused by improper management and utilization of natural resources, and to ensure that the development activities are conservation-based.

The powers and duties of EPLAUA are to:

- Study the geography of the region and determine land use;
- Prepare proposals on environmental strategy and laws of the region based on the federal environmental policy and implement upon approval;
- Develop systems that facilitate environmental impact assessment and follow up and monitor the implementation of development projects in an environmentally friendly manner;
- Study the use and management of the regional biodiversity resources, natural and man-made heritage and parks;
- Prepare environmental standards for the region in line with the federal environmental directives; and
- Educate the communities so that they protect their environment.

The EPA should act in an advisory capacity to the EPLAUA which is designated to deal with environmental issues, land administration and use at the regional level. Project proponents and executive agencies in the region should operate in close cooperation with the EPLAUA to ensure that proper mitigating measures are designed and implemented, especially where there are adverse effects on the environment. The national environmental policies, laws and international conventions that Ethiopia has ratified emphasize the utilization of environmental resources in a sustainable manner, which require scientific assessments of the various components of the environment.

Lake Tana Fisheries

Eshete Dejen
PO Box 527 Bahir Dar Ethiopia

4. Introduction

Fish is an important ecological and economic component of the Lake Tana sub-basin. Although several studies have been made on fish in this lake, they focused on pure biology. The management aspect and its interaction with the Lake-River-Wetland ecosystem continuum have not been investigated. Moreover, the environmental impact assessment of the proposed development interventions (dams on rivers, tunnels for hydro-electricity, etc) requires information on the fish types and potential of the river's fishery. This study therefore investigated the management aspects, including the role of wetlands in supporting fish biodiversity, with the aim of generating results for management purposes.

The freshwater fish fauna of Ethiopia is of particular interest since it contains a mixture of Nilo-Sudanic, East African, and endemic forms (Roberts, 1975, Getahun & Stiassny, 1998). The Nilo-Sudanic forms are represented by a large number of species found in the Baro-Akobo, Omo-Gibe, and Abay drainage basins (eg. members of the genera *Alestes, Bagrus, Citharinus, Hydrocynus, Hyperopisus, Labeo, Mormyrus* etc). The southern Rift Valley (Lakes Abaya and Chamo), and the Shebele-Genale basins also have elements of these forms. It is believed that these lakes and river basins had former connections with the upper White Nile (through Lake Rudolf in the former case) as recently as 7,500 years ago (Roberts, 1975). These Nilo-Sudanic forms are related to West African fishes and this too is believed to be due to past connections of the Nile to Central and West African river systems (Boulenger, 1905: Nichols & Griscom, 1917; Nichols, 1928).

The highland east African forms are found in the northern Rift Valley lakes (eg. Lakes Awassa, Ziwai, Langano), the highland lakes (e.g. Tana and Hayq) and associated river systems, and the Awash drainage basin. These include members of the genera *Barbus, Labeobarbus, Clarias, Garra, Oreochromis*, and *Varicorhinus*. They are related to fishes of eastern, northern and southern Africa. Some species can also be found in western Africa. For example, *G. dembeensis* is a widely distributed cyprinid species found in 6 countries (Cameroon, Egypt, Ethiopia, Kenya, Nigeria and Tanzania). Nilotic fishes are almost entirely absent from the Awash and northern Rift Valley lakes.

Although extensive review work is currently in progress, it appears that a preliminary listing of about 152 indigenous species represents what is so far known from Ethiopian freshwaters. There are additionally 10 exotic species. Of the 152 indigenous species, about 39 species and two sub-species are endemic to Ethiopia. Ongoing extensive collections and identifications may raise both the total number and the number of endemic species.

The highest species diversity is recorded from Baro basin, followed by Abay, Rift Valley Lakes, Wabi Shebele and Omo-Gibe basins. It appears that this high diversity is partly attributable to the presence of highly diverse and rich habitats, but probably also to relatively high levels of exploration and collections done in these relatively accessible water bodies. However, endemicity seems to be highest in Abay and Awash basins. This is due to the endemic "species flock" of Lake Tana and the presence of some endemic fishes adapted to localized habitats in small streams in the highlands of north and central Ethiopia. Lake Tana has 28 species and one sub-species, of which 20 species and one sub-species are Ethiopian endemics. 18 species are endemic to Lake Tana.

The drainage basins that are rich in species, like the Baro and Omo-Gibe, contribute an insignificant proportion of the country's endemic fauna. Only one endemic species (*Nemacheilus abyssinicus*) has so far been recorded from these drainages and this species has also been recorded from Lake Tana. Low levels of endemism are probably due to the Baro and Omo-Gibe drainage basins having connections (present and past) with the Nile and west and central African river systems, with the result that all the fish fauna represent widespread Nilo-Sudanic forms.

The major commercially important fish species of the country include *Oreochromis niloticus*, *Labeobarbus* spp., *Lates niloticus*, *Clarias gariepinus*, *Bagrus docmak*, and the introduced carp *Cyprinus carpio*.

4.1 Objectives

The objectives of this study were to:

a. describe the diversity of the fish species
b. describe the ecological and economic role of the fish species
c. assess the fish stock of the lake, rivers and wetlands
d. describe the legal, institutional and social aspects for fisheries management

4.2 Methods

4.2.1 Literature review

In order to identify knowledge gaps, literature from different sources were reviewed from sources like Bahir Dar Fishery and Aquaculture Research Center, Bureau of Water Resources, Environmental Protection Agency, Bureau of Agriculture, Bahir Dar University, The University of Wageningen in the Netherlands, the Russian Academy and unpublished reports. Long term fish catch and effort data were taken from Bahir Dar Fishery & Aquaculture Research Center and assessed for trends.

4.2.2 Sampling program

Fish species and their habitats were sampled and analysed from three ecosystems: the Lake, the wetlands and the rivers. Sampling material and laboratory analysis were carried out at Bahir Dar Fishery & Aquaculture Research Center.

4.2.3 Stakeholder consultations

A structured questionnaire was developed to assess institutional and legal aspects of fish resource management. Fisher-folk, policy makers, researchers, development workers, fish processors and traders were interviewed. Institutions at the regional and national government-level that deal with research, agriculture and water issues were also consulted.

4.3. Results

4.3.1 The Lake Tana fish species

During the study, 27 fish species (Table 4.1) were recorded from Lake Tana, of which 19 are endemic.

Table 4.1. The species of fish identified from Lake Tana and its associated rivers.

Family	Genus	Species
Cyprinidae	*Labeobarbus*	*acutirostris*
Cyprinidae	*Labeobarbus*	*brevicephalus*
Cyprinidae	*Labeobarbus*	*crassibarbis*
Cyprinidae	*Labeobarbus*	*dainellii*
Cyprinidae	*Labeobarbus*	*degeni*
Cyprinidae	*Labeobarbus*	*gorguari*
Cyprinidae	*Labeobarbus*	*gorgorensis*
Cyprinidae	*Labeobarbus*	*intermedius*
Cyprinidae	*Labeobarbus*	*longissimus*
Cyprinidae	*Labeobarbus*	*macropthalmus*
Cyprinidae	*Labeobarbus*	*megastoma*
Cyprinidae	*Labeobarbus*	*nedgia*
Cyprinidae	*Labeobarbus*	*platydorsus*
Cyprinidae	*Labeobarbus*	*surkis*
Cyprinidae	*Labeobarbus*	*truttiformis*
Cyprinidae	*Labeobarbus*	*tsanensis*
Cprinidae	*Barbus*	*humilis*
Cyprinidae	*Barbus*	*pluerogramma*
Cyprinidae	*Barbus*	*tanapelagius*
Cyprinidae	*Garra*	*dembecha*
Cyprinidae	*Garra*	*dembeensis*
Cyprinidae	*Garra*	*regressus*
Cyprinidae	*Garra*	*tana*
Cyprinidae	*Varicorhinus*	*beso*
Cichlidae	*Oreochromis*	*niloticus*
Claridae	*Clarias*	*gariepinus*
Balitoridae	*Nemacheilus*	*abyssinicus*

The largest fish family in the lake is the Cyprinidae, which are represented by four genera: *Barbus, Garra*, *Labeobarbus* and *Varicorhinus*. *Varicorhinus* is represented by a single species *V. beso*, which feeds by scraping algae from substrates, and which is a common species in the rivers and lakes of the Ethiopian Highlands. The genus *Garra* is represented by four species in Lake Tana: *G. dembecha* (Boulenger), which is common and generally distributed in the Ethiopian Highlands; *G. dembeensis,* found on the northern part of Lake Tana; and two endemic species, *G. regressus* and *G. tana*, recently described by Getahun (2000). All four species are herbivorous. Fifteen large (max. 100 cm length) hexaploid barbs (*Labeobarbus* spp.) belong to a unique species flock of endemic cyprinids; surprisingly eight of these are piscivores (Nagelkerke & Sibbing, 2000). The adult *Labeobarbs* are generally pelagic, whereas the juveniles usually live in the littoral zone with macrophytes and/or in the adjacent wetlands. One non-endemic labeobarb species is present, *L. intermedius*, a generalist that feeds mainly on macrofauna and benthic invertebrates. It can be found all over Ethiopia in lakes and rivers. The fish community also includes three diploid species of small (<10cm) barbs: *Barbus humilis*, *B. pleurogramma* and the recently discovered *B. tanapelagius* (de Graaf *et al*., 2002). The last two species are endemic to Lake Tana with *B. pleurogramma* mainly present in the wetlands around the lake and *B. humilis* is a littoral species. However, *B. tanapelagius* is common in the large pelagic zone of the lake.

One cichlid, *Oreochromis niloticus* (Nile tilapia), the most widespread tilapia species in Africa, occurs in the lake. This species is predominantly herbivorous, feeding on macrophytes, algae and detritus. The catfish family (Clariidae) is also represented by one species, *Clarias gariepinus* (African catfish), which is the most common member of its genus. This species is a facultative piscivore, also feeding occasionally on zooplankton, benthic invertebrates and algae. The obscure loach, *Nemacheilus abyssinicus* (Balitoridae), is very rare in the lake but has been observed in a small stream close to Lake Tana and in large parts of the Ethiopian high plateau (Dgebuadze *et al*., 1994). Interestingly, this loach is the only species of this Palearctic family known from Africa (Nagelkerke, 1997).

The speciation of fishes in the LTSB was possible because approximately 5 million years ago the lake was isolated from the lower Blue Nile basin by a 40m high waterfall along the Blue Nile outflow (Nagelkerke & Sibbing, 2000).

4.3.2 Endemism in Lake Tana

Barbus humilis is a riverine species and more widely distributed in the inflowing rivers of Lake Tana and littoral habitats. It is highly likely that *B. tanapelagius* evolved out of a *B. humilis*-like ancestor following the rise of large pelagic zooplankton resources after the lake dried up and filled with water again, ca. 16,000 years ago. Investigation on the phylogenetic relationships of the two barbs using the mtDNA cytochrome b gene showed that the genetic divergence between the two species was very low (de Graaf *et al*., 2007).

The 15 large barb species (*Labeobarbus* spp) comprise a unique concentration of endemic cyprinid fish (Nagelkerke & Sibbing, 2000). The species occupy different habitats as characterised by water depths and substratum types (Nagelkerke *et al*., 1994). Seven of these species do not spawn in the lake itself, but in one of the permanent rivers (de Graaf *et al*., 2005). They did not show spatial segregation among inflowing rivers but significant temporal segregation occurs as they aggregate in the river mouths and as they migrate towards the upstream spawning areas during the breeding season (June-October). Among the eight other species, peak gonad development occurred generally in the same period as in the riverine spawners, but they did not aggregate in the river mouths during the breeding period and were absent from the upstream spawning areas. Most probably they spawn in the wetlands where their juveniles also feed and grow (Palstra *et al*., 2004).

A likely scenario for the evolution of fish species in the Lake Tana sub-basin is as follows (Nagelkerke & Sibbing, 1996): after Lake Tana was formed, through volcanic blocking of the Blue Nile River, a population of riverine labeobarbs was present. This was probably a species resembling the riverine *L. intermedius*, which is still found throughout Ethiopia today both in rivers and in lakes. The populations of *L. intermedius* are known to be highly variable in morphology (M. Mina pers. comm.). The formation of Lake Tana resulted in an extensive new lake area becoming available, providing new lacustrine habitats with their specific resources. Around the same time, incipient morphotypes might have radiated into different niches; this probably started from the inshore areas, which resemble the riverine habitat more closely than the open water zone of the lake, possibly because of the presence of macrophyte vegetation. Genetically basic morphological differentiation became fixed by assortative mating. In the riverine spawning species this occurred by temporal segregation during the aggregating phase in the river mouths and during the migration phase towards the upstream spawning areas.

4.3.3 Fish community structure and food utilization

The *Barbus* and *Labeobarbus* species dominate the fish community in terms of biomass and production (Wuddneh, 1998; Dejen *et al*., in press). Zooplankton is highly utilised by the fish community (Dejen *et al*., 2007). The three *Barbus* spp., the juveniles of all 15 *Labeobarbus* spp. and the adults of *L. brevicephalus* feed all on zooplankton. *B. tanapelagius* is, however, the only obligate zooplanktivore and the other species utilise also other animal food items. *Barbus pleurogramma* maintains the most benthivorous diet, whereas *B. humilis,* juvenile labeobarbs and *L. brevicephalus* feed for approximately half (by biovolume) their diet on zooplankton and for the other half on adult floating insects, insect larvae and benthic invertebrates. *B. tanapelagius* and the adults of *L. brevicephalus* occupy the same habitat, the large pelagic, and both actively select *Daphnia* as prey item.

Eight of the fifteen endemic *Labeobarbus* spp. (more than 65 % of all labeobarbs) are piscivorous: two are obligate piscivores (*L. acutirostris*, *L. truttiformis*) and six facultative piscivores (*L. dainellii*, *L. gorguari*, *L. longissimus*, *L. macrophtalmus*, *L. megastoma*, *L. platydorsus*) (Sibbing & Nagelkerke, 2001). Experiments showed that these piscivores are very clumsy predators, most probably because they have a narrow pharyngeal slit and lack teeth on their oral jaws (de Graaf, 2003). Most probably, these species can only survive because specialised and more efficient non-cyprinid piscivores are lacking in their habitat. The piscivorous niche of these co-occurring species is segregated by habitat, diet composition and prey size (de Graaf *et al*., 2004). The main prey items eaten were *B. humilis* (40 % of the gut contents), *B. tanapelagius* (32 %) and *Garra* species (21%). Therefore, the two small barbs form the main link between the zooplankton and the piscivorous fish in the food web of the lake.

Besides piscivores, there are five other trophic groups of labeobarbs. One species feeds on macrorophytes (*L. surkis*), one upon macrophytes and molluscs (*L. gorgorensis*), one species on macrophytes and adults insects (*L. osseensis*), one species predominantly on zooplankton (*L. brevicephalus*) and four species are benthivorous feeding mainly on chironomid larvae and on macrofauna associated with macrophytes (*L. crassibarbus*, *L. intermedius*, *L. nedgia*, *L. tsanensis*). Although the food web of Lake Tana is very complicated, it is presented in a simplified form so that managers can easily understand major components supporting the lake ecosystem (Figure 4.1).

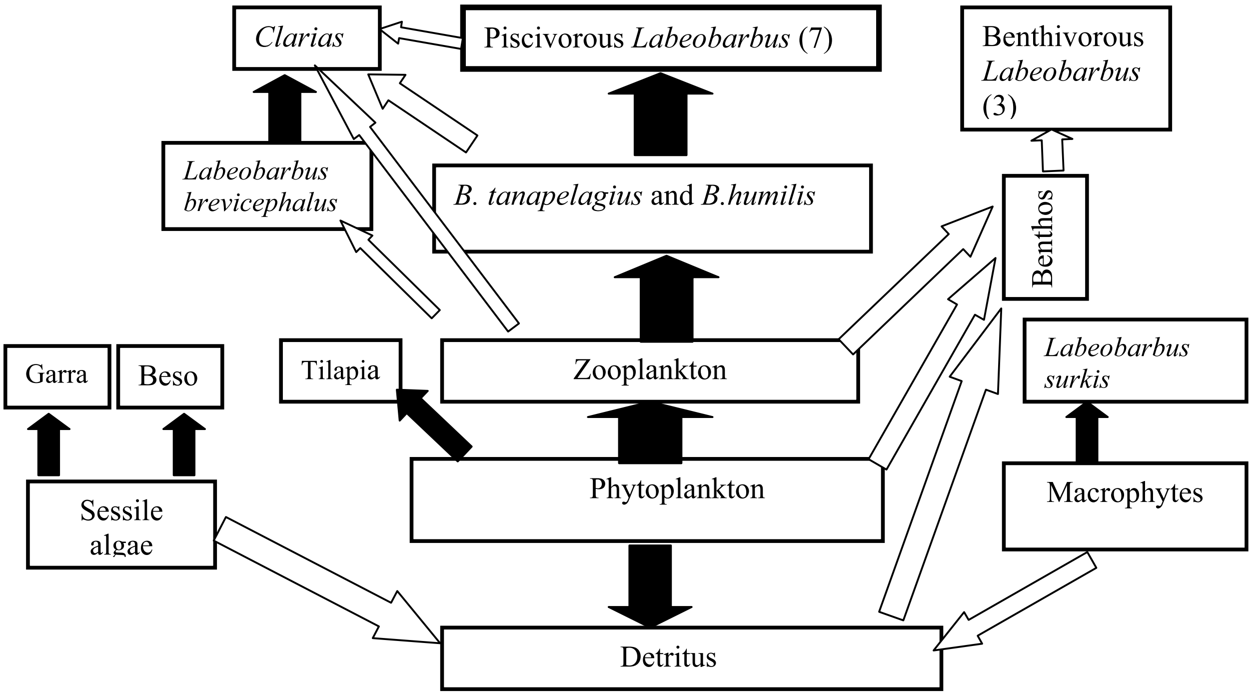


Figure 4. 1. Simplified food web of Lake Tana (Getahun *et al*., 2008)

4.3.4 Reproductive biology of fish stocks in Lake Tana

The reproduction biology of the commercially important species in the lake provides vital information required in designing fisheries management strategies. It answers important questions regarding size at first maturity, timing of the breeding season and locality of spawning sites for each species. Such information is used to set the minimum allowable fish size in the catch and protect the breeding stocks, which become vulnerable as they aggregate at the spawning grounds. Management measures could involve the introduction of a minimum mesh size and setting closed seasons and/or areas. Sustainable fisheries management requires that fishing gears which harvest large mature fish while allowing small juveniles to escape are used.

From several studies undertaken in Lake Tana, sizes at maturity for females were 30.5cm, 18cm and 20.5cm for African catfish, Nile tilapia and *Labeobarbus tsanensis* respectively (Table 4.2). Male African catfish and Nile tilapia mature at larger sizes of 36cm and 20.5cm respectively. For *Labeobarbus* species, size at maturity varies depending on the species. However, their breeding season is from mid-July to end of November.

Table 4.2. Size at maturity of some fish species for both sexes (male & female)

Species	Size at first maturity (cm)	
	F	M
L. acutirostris	33	25.5
L. brevicephalus	18.2	-
L. crassibarbis	44.1	28
L. dainellii	24.8	22.1
L. gorgorensis	46	-
L. gorguari	34.3	-
L. intermedius	26	-
L. longissimus	37.8	-
L. macrophtalmus	27	19.6
L. megastoma	36.1	26.5
L. nediga	29.7	19.8
L. platydorsus	37	24.4
L. surkis	32.9	-
L. tsanensis	26	17.7
L. trutiformis	26.6	21.8

Periodicity of breeding is most distinct for African catfish. Peak breeding occurs in July, when they migrate to newly-inundated marginal areas, and lasts for 2 months. Extended breeding seasons of about 3 to 4 months were observed for *Labeobarbus* species, whilst Nile tilapia breed throughout the year in shallow areas of the lake and marginal wetlands (Table 4.3).

Table 4.3 Summary of reproduction, diet, growth and susceptibility to fisheries for three fish types in Lake Tana

	Labeobarbs	**African Catfish**	**Nile Tilapia**
Reproductive Biology			
Spawning period	2-4 months August-November	2 months July-August	All year
Spawning aggregations	River mouths	None	None
Spawning areas	Floodplains Upstream rivers	Floodplains	Floodplains
Ecology			
Diet	Specialists	Generalist with broad diet spectrum	Generalist feeding mainly on algae and detritus
Habitat	Specialists	Bottom-dwelling All over the lake	Water column Inshore zone
Growth			
Age at maturity	3-5 years	2-3 years	1-2 years

			Highly flexible
Susceptibility to Fisheries	High Vulnerable	Moderate Resilient	Low Most resilient

The *Labeobarbus* species are riverine fishes which have become adapted to the lake. However, most of this genus still migrates upstream to spawn in the rivers and their tributaries. In Lake Tana, only three of the rivers flowing into the lake (Gumara, Megach and Ribb Rivers) were sampled. There is clear evidence that at least 8 *Labeobarbus* spp. migrate upstream to rivers during the rainy season. Therefore rivers are important breeding grounds for this fish stock. Reproductive characteristics of non-commercial species like small *Barbus* were investigated. All small *Barbus* breed in the lake from March-September.

4.3.5 Role of rivers and wetlands for fish production

Most African barbs occur in rivers. In general, large *Barbus*, including lake dwelling species, are considered to be riverine-spawners that migrate upstream to spawn, over a short period, in shallow gravel beds within fast flowing, small rivers.

In Lake Tana, the prevailing, actual differences in the reproductive characteristics and spawning patterns of African barbs need to be investigated. Detailed information on gonad development, peak breeding period, spawning area and size at maturity of each of the 15 species was, until recently, scarce, fragmented and sometimes unreliable due to limited sampling. The scanty information available is restricted to the southern part of Lake Tana and the Gumara, Rib and Megach Rivers.

The general requirements for *Barbus* spawning include highly oxygenated water and gravel beds. This is due to their critical importance in the development of eggs and larvae. These rivers are well oxygenated upstream by rapids and also have tributaries which are suitable grounds for spawning. Deposition of eggs in gravel beds prevents them from being washed away and facilitates the diffusion of oxygen. Final maturation and spawning of *Labeobarbus* spp. occurs in the tributaries and for some large species possibly at gravel areas in the far upper reaches of the rivers' main channels. This has been deduced from the distribution of running females. Moreover, some pools across the main river channels serve as a habitat for feeding and reproduction of river-resident *Labeobarbus intermedius* and *L. nedgia*.

The river mouths and the surrounding wetlands of Lake Tana are important habitats for reproduction and feeding of the three commercially important fish species. If seasonal flood plains are lost as a result of the dam or any other intervention, there will be substantial losses to the fisheries of floodplain river-lake ecosystems. It is therefore advisable to maintain the existing annual flooding of the wetland areas.

4.3.6 Lake Tana fisheries production

(i) Fishery sector in Ethiopia

The importance of fisheries to the Ethiopian economy, until 50 years ago, was insignificant due to abundant land-based resources and a sparse population density. But, from the 1940s and 50s, the rapid population growth, which resulted in a shortage of cultivable land and depletion of land resources, forced the people to look for other occupations and sources of food from water resources at a subsistence level. Also, the rapidly growing demand for fish in the capital city by foreigners and modern town dwellers contributed to the start of commercial fishing as a new practice in Rift Valley lakes (from the 1950s) and, later, in Lake Tana (late 1980s). Even though no systematic survey and assessment of the potential of all water bodies have been made, the rough potential harvest estimate from an area of 7,005 km^2 and 7 main lakes, 2 small lakes and 1 reservoir was about 51,500 tons/year. Fishery potential for rivers and other small water bodies is absent. According to the FAO (1995), an estimated annual potential of 25,000 tons has been calculated for River Baro.

The available data on actual fish production in Ethiopia indicate that the total fish landed in 1996 was about 8,500 tons (Reyntjens & Wudneh, 1998). The FAO (2003) estimated that in 2001, fish production was 15,400 tons.

The general view seems to be that the lakes in the south are heavily exploited. For 8 important landing sites on lakes, the FAO (2003) estimated that off-take exceeds 60% of the potential in 7 sites and 80% in 5 sites (including Awassa where off-take is estimated at 140% of potential). Only in Lake Tana is off-take dramatically less than potential (15-20%). The traders in Addis Ababa substantiate this trend that fish size from the south is getting smaller and the catch is reduced from these over-exploited water bodies.

Domestic supply is only supplemented by imports to a very small extent. FAO (2003) indicated that 36 tons of fish were imported in 2001. This import is likely to be mainly canned marine fish and high value fish (possibly including small amounts of Nile perch from other East African countries) destined for big hotels and supermarkets.

(ii) Lake Tana fisheries

An estimated human population of two million resides on the islands and around Lake Tana. Historical accounts show that the indigenous people who lived around the lake belong to the ethnic minority Negada-Weyito. Fish used to be the main food source for this and other communities living in the areas surrounding the lake.

Lake Tana is one of the few African lakes which have not yet been damaged by introduced fish species or major sources of pollution. Prior to 1986, Lake Tana fisheries consisted only of an artisanal, predominantly subsistence reed boat fishery. This type of fishery was limited to the shore areas and targets the native Nile tilapia, Beso and *Labeobarbus* using locally-made fish traps and gillnets (length 15-20 m).

Fishing in Lake Tana started around the 18th century by the Negada-Weyito community; the other poor members of the communities gradually adopted the activity. In 1986 the Lake Tana Fisheries Resource Development Program (LTFRDP) was started by a Dutch non-governmental organization the Interchurch Foundation Ethiopia (ISE-Urk) in collaboration with the Ethiopian Orthodox Church and the Ministry of Agriculture. The assistance program targeted the poor fishermen around the Bahir Dar Gulf area and nearby islands by introducing modern fishing gear and motorized boats.

The LTFRDP created new opportunities for the fishers, extending their fishing area from the shore to deeper, offshore waters and, more importantly, to distant river mouths. Moreover, with the increase in catch, fish processing, marketing and net-making activities emerged as job opportunities for the surrounding communities.

Currently, four major types of fisheries exist, characterized by the following specific combinations of gear and fishing crafts:

1) the motorized gill net (mesh sizes 10-12 cm) fishery based in Bahir Dar and now expanding into 10 bordering Woredas;
2) the traditional reed-rafts-gillnet (mesh size 6 to 10 cm) around the lake
3) the traditional reed-rafts-gillnet (mesh size 10 to 12 cm)
4) the chase and trap fishery (mesh size 6 to 9 cm) based in the southern part of the lake.

Gear such as long-lines, cast nets and traps are occasionally used but contribute very little to the total fish catch.

The traditional reed boat fishery is still important for remote areas of the lake. Reed-boats normally carry only one fisher and catch is collected early morning. The catch from this fishery is sold at small markets in the village and used for household consumption. They target mainly tilapia fish species. The total number of reed boats is estimated to be about 400, or some 400 fishers (Tegegne, 2003). Reed boat fishers are not organized into any association or cooperative.

The recently introduced motorized fisheries mainly target bigger markets. This fishery method uses engine boats with 100 m long gillnets of 10-14 cm stretched mesh size. The motorization program was accompanied by the organization of the fishers into an association and subsequently with technical training in net-making, fish processing and engine maintenance. The motorized boats are mainly steel boats. There are about 25 motorized fishing boats on the whole lake, most of which land their catch in Bahir Dar (either directly or via a collector boat).

The advantage of belonging to fishers' associations is that credit and technical assistance becomes available. There are three fisheries cooperatives in Bahir Dar:

(i) Tana Haik I Fishers' Cooperative - established in 1987 with the help of LFDP (Lake Fisheries Development Project) and has 78 members. They have 6 motorized boats with 210 standardized mesh gillnets. Currently the cooperative has 150 members who work on different activities: fishing, processing and selling of fish in different product types, and on provision of fishing materials especially modern gillnets. This Cooperative appears to be well-managed as a producer cooperative enterprise and has sought to incorporate smaller producer groups operating at kebele-level, in a bid to improve efficiency and realize economies of scale;

(ii) Kidus Giorgis Fishers' Association - the Kidus Georgis Fishers Association has also created job opportunities for about 22 individuals, who are participating in fish production, collection, processing and selling. They have also made a great contribution in satisfying the demand for fish by the local people

(iii) Zeghe Fish-For-All Association - the Zeghe Fish-For-All Association is located at Zeghe peninsula. It has 40 members and has owned about 50 gillnets and 5 motorized boats. This association does not have any freezing capacity, so it sells its catch to Giorgis or to the Fish Production & Marketing Enterprise (FPME) .

The FPME is a parastatal entity working in fish production and fish marketing at the local markets. The enterprise was established in 1978 by the Ministry of Agriculture. The enterprise has 9 motor boats each with a 20x100m gill net and each boat works 6 days per week. It has cold storage facilities for 15 tons at the landing site in Bahir Dar as well as refrigerated transport facilities.

The main supplier of fish from Lake Tana to Addis Ababa is the FPME with about 30% of the fish handled by FPME nationally being sourced from Lake Tana. All of its barbus and most of its tilapia and catfish comes from Lake Tana. This represents about 300-400 tons per year (weight of whole wet fish).

Other associations are now emerging across 10 surrounding woredas and it is anticipated that each woreda will have at least 1 association with 80-120 members.

The lake fishery has employed more than 3,000 individuals who are directly dependent on the major activities of fishing, marketing and processing for their livelihood (Table 4.4). It is also providing employment opportunities to women and other landless people, such as ex-soldiers, as well as the fishers.

Table 4.4 Dependents in the fishery sector directly involved in fishing and post harvest (Demisse, 2003)

Activities	Households	Dependents	Total
Fishing	596	2,384	2,980
Fish trading (self-employed)	26	-	26
Fish processing employment in the FPME and the cooperatives	52	208	260
Others (associated activities like nets, gear, fishmeal, etc)	33	132	165
Total	**707**	**2,750**	**3,431**

4.3.7 Seasonality in the fishery and fishing areas

The fisheries in Lake Tana are seasonal. There are some seasons where some or all fish species are abundant. Understanding the seasonality of fish catch will help in planning fishing activities. Historical records show the following seasonality in species catch:

- March-August: highest catch levels from Lake Tana.
- October-November: lowest catch levels from Lake Tana
- November-May: harvest period from seasonal ponds
- January-July (especially March/April/May): tilapia most common fish in the catch
- June-September (especially June/July): catfish most common in the catch
- June-September (especially August): barbus most common fish in the catch.

Closely associated with the lake fishery are: (a) the natural seasonal ponds (mostly on the eastern shore) that are linked to the lake and which flood during the rains - producing tilapia or catfish; and (b) the rivers, which are important spawning grounds for lake barbs. Fishing around Lake Tana takes place on three areas: the lake, the natural pond and rivers. Fishing on the lake accounts more than 95 % of fishing in the area. The fishing on the lake takes place throughout the year, except during October-November when fishing effort decreases.

In Fogera Woreda (eastern part of the lake), there are two large seasonal ponds that are connected to the lake and flood during the rainy season. As the waters recede, these become extremely productive ponds for catfish which are caught in the period from February-May with gill nets and spears by large numbers of local farmers turned seasonal fishermen (perhaps around 600). The catch is dried (women help with this aspect) and sold to traders who export it to the Sudan. There is also another pond at Dera Woreda (around Hamusit) that produces wild tilapia, which is sold fresh.

The rivers are important spawning grounds for lake barbels, and are also a source of tilapia and catfish. Around 400 people are involved in the fishery in Gumara River, on a part-time or seasonal basis, with fishing (using traps) particularly pronounced during the official closed season for barbus (August-October). The spawning season, when there is most fishing activity, coincides with the lean season, so the fishery represents a seasonally important source of sustenance and income for some households (Gordon *et al*., 2007).

4.3.8 Species composition of Lake Tana

Bahir Dar Fisheries and Aquaculture Research Center conducted monthly fishing experiments using 100 m long gill nets of 6, 8, 10 and 12 cm stretched mesh size (Table 4.5). There is temporal and spatial variation in abundance of different fish species. Their habitat was classified into river mouth, inshore and offshore.

Table 4.5 Summaryof species numbers and percentage compositions from monthly samples per site over a 5 year period (2000 to 2004) (BAFLRC, 2007)

	River Mouth				Inshore				Deep-water			
	Abay		Dirma		Gerima		Gedamat		Sekela		Zeghe	
Species	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
L. acutirostris	229	4.5	108	3.3	35	2.4	29	2.8	26	0.9	66	6.3
L. brevicephalus	383	7.4	360	11	203	13.5	57	5.4	309	10.8	302	28.8
L. crassibarbis	75	1.5	51	1.6	8	0.5	16	1.5	23	0.8	45	4.3
L. dainellii	0	0	5	0.2	8	0.5	24	2.3	9	0.3	1	0.1
L. gorgorensis	46	0.9	26	0.8	13	0.9	11	1.1	48	1.7	9	0.9
L. gorguari	0	0	4	0.1	0	0	13	1.2	2	0.1	0	0
L. intermedius	2338	45.4	374	11.4	259	17.2	177	16.9	116	4.1	286	27.2
L. longissimus	29	0.6	2	0.1	13	0.9	9	0.9	7	0.2	4	0.4
L. macrophtalmus	78	1.5	18	0.6	6	0.4	14	1.3	40	1.4	21	2
L. megastoma	203	3.9	135	4.1	45	3	29	2.8	25	0.9	14	1.3
L. nedgia	76	1.5	3	0.1	10	0.7	20	1.9	0	0	16	1.5
L. platydorsis	165	3.2	46	1.4	9	0.6	8	0.8	107	3.8	72	6.9
L. surkis	19	0.4	114	3.5	33	2.2	60	5.7	6	0.2	0	0
L. tsanensis	131	2.5	1127	34.4	23	1.5	175	16.7	1039	36.4	148	14.1
L. truttiformis	19	0.4	72	2.2	23	1.5	175	16.7	4	0.2	7	0.7
O. niloticus	731	14.2	451	13.8	594	39.5	101	9.6	10	-	7	0.7
C. gariepinus	559	10.9	380	11.6	157	10.5	98	9.4	49	1.7	52	5
V. beso	68	1.3	34		63	4.2	32	3.1	4	0.2	0	0

In the river mouths habitat, *Labeobarbus intermedius* and *Labeobarbus tsanensis* were the predominant species. In the inshore habitats *Oreochromis niloticus* is the most abundant followed by *Labeobarbus intermedius* and *Labeobarbus tsanensis*. In the offshore habitat *Labeobarbus tsanensis* and *Labeobarbus brevicephalus* are the dominant species.

Six *Labeobarbus* species dominated the experimental data catch: *L. acutirostris, L. brevicephalus, L. intermedius, L. platydorsis, L. truttiformis* and *L. tsanensis*. These six species contribute to the fishery of Lake Tana in addition to three other species: African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*) and Beso (*Varicorhinus beso*).

4.3.9 Fish catch trends from Lake Tana

In addition to the artisanal, predominantly subsistence reed boat fishery, a motorized commercial gill net fishery was introduced to Lake Tana, which led to a total catch increase from 39 tons in 1987 to 360 tons in 1997. Reed boat fishery data was also collected by the Lake Fisheries Development Project (LFDP) from 1987 to 1996. The annual catch fluctuates and reached a peak in 1994 (Table 4.6). The majority of the catch comes from the traditional reed boat fishery.

Table 4.6. Fish catch data in tons for motorized and reed boat fishery in Lake Tana (LFDP, 1997)

Year	Reed boat catch (ton)	Motorized boat catch (ton)	Total	% contribution of reed boat fishery
1987	522	348	870	60
1988	865	280	1,145	76
1989	1,109	360	1,469	75
1990	945	307	1,252	75
1991	645	250	895	72
1992	602	202	804	75
1993	773	252	1,025	75
1994	1,157	357	1,514	76
1995	663	231	894	74
1996	756	237	993	76

In recent years, catch from the lake has been increasing. This is due to several reasons, including the following: the price of fish has increased, the fisher cooperatives are organized throughout the lake and there is a lack of employment in other sectors.

Total fish catch from Lake Tana was estimated by the Regional Bureau of Agriculture and Rural Development as follows:

Year	Annual Catch (tons)
2003	1,068
2004	1,231
2005	1,281
2006	3,004

In the 1990s the species composition of the commercial catch comprised large *Labeobarbus* spp. (40%), African catfish (*Clarias gariepinus*) (25%) and Nile tilapia (*Oreochromis niloticus*) (35%). In 2007, the percentage composition of these same species had shifted to 15%, 21% and 64% respectively. There has been a sharp decline in the catch of endemic *Labeobarbus* species, which needs serious attention for the sustainable development of Lake Tana fishery (Getahun *et al*., 2008).

Assuming a sustainable annual maximum yield of 10,000 tons, the 2006 catch of 3,000 tons represents only 30% of the lake's potential. A fish processing factory is being finalized at the southern gulf of Lake Tana with the capacity to process 3,000 tons of fish per year.

4.3.10 Decline of *Labeobarbus* spp. from Lake Tana

The commercial gillnet fishery on *Labeobarbus* is highly seasonal as more than 50% of the annual catch is obtained from the river mouths during August and September (Wudneh, 1998). Catch per unit effort (CpUE) of *Labeobarbus* species from the commercial gill net fishery dropped from 63 kg/trip in 1991 to 28 kg/trip in 2001 (de Graaf *et al*. 2003). At the same time, declines of 75% in biomass and 80% in number were reported for six *Labeobarbus* species in the southern gulf of Lake Tana, which calls for urgent measures to be taken to conserve this endemic species flock (Getahun *et al*., 2008).

Recruitment overfishing by the commercial gill net fishery (de Graaf *et al*., 2004) and poisoning of the spawning stock by the fishermen near the river mouths using the crushed seeds of the birbira tree (*Milletia ferruginea*) (Nagelkerke 1997) were the most plausible explanations given for the decline of the stock. This explanation applies to the southern gulf of the lake. However, this conclusion didn't generalize for the whole lake as the largest area of the lake (> 60%) is situated in the north which was not included in the previous studies. In the northern part of lake, fishing is still subsistence using only reed boats. Hence, recruitment overfishing could not be the reason for the decline of the stock. However, the degradation of reproductive habitats (rivers) as a result of agricultural activities and excessive sand extraction might have been responsible factors for the decline of the stock in this part of the lake.

4.4 Fish marketing in Lake Tana

The Fish Production and Marketing Enterprise (FPME) is the main market outlet for Lake Tana's fishery. This reduces the opportunities for fishers to negotiate a reasonable price for their fish. Fish is also distributed directly at landing to local consumers to satisfy the local demand. This ensures a reasonable price to consumers and a reasonable return to intermediaries due to the almost zero cost of transportation and other additional costs.

However, it is not the same situation in all corners of the lake. In the northern part of the lake, for example, due to limited access to markets (other than for local consumers) and given that the landing sites and town are far apart, transportation of quality fresh fish to the town market is a critical problem. Thus, the price of fish is low for all traders, unlike in the south where the fishers have good access to the potential traders and market (as the town of Bahir Dar, the FPME, cooperatives and other traders are all nearby).

It has been reported by the communities that dried fish is being exported to Sudan from woredas around the Lake. This is a marketing opportunity that should be explored.

Until 2004, the price of fish was low (0.8 birr/kg – when the price of beef was 8 birr/kg, ie 10%) but then increased (FPME, 2007) and it is currently at a price at least 50% of the beef price.

Lake Tana is considered a rich source of fish, which generally does not yet show signs of over-fishing, but it is a relatively high cost source of fish. With tightening of the market and rising prices, fish traders have started to take more interest in Lake Tana and a number of new small scale operations have developed. High costs stem from: high landing costs because there are relatively few places where fish can be landed; the costs associated with shipping the long distance to Addis Ababa; and spoilage associated with the time lapse from capture to freezing and during transit to Addis Ababa.

Due to high cost in the commercial fishery, the marginal gain does not permit the motorized fishery to expand even though the resource potential is high. It is, therefore, important to stress that the Lake Tana fishery finds itself in a unique but rather problematic situation. On the one hand, the present fish stock allows some intensification of the fishing pressure, while on the other hand socio-economic and market conditions are too poor to capitalize on the resources. Hence, the government's objective to expand the motorized fishery can only be met by alleviating these constraints. In this respect, promotion of fish consumption at higher *per caput* consumption rates is crucial. If such a goal can be attained a viable intensification of the fishing industry is possible. In that case an increase of fishing effort should be coupled with, or preceded by, appropriate fishery legislation and management regulation, to ensure biological sustainability of the fish stock and the environment that are the bases of the fishery.

4.4.1 Benefits from fishing and related businesses

a) *Food source*

From the survey result of Demessie (2003), fish is found to be included as a part of the family meal at least 1 or 2 days per week or an average of 146 days per year by each family of the respondents. Although the data is based on respondents' opinion and the figure given is the number of fish eaten, the weight-converted average daily consumption of one family is estimated to be nearly 1kg.

b) *Income source*

From the traders information one fisher working with a papyrus reed boat can produce an average of 22.3 kg of fish per day. Traders can obtain a minimum of 9 kg of fish in a bad season, and up to 45 kg in a good season. However, this information is based on the amount traders can get and sell on the market, which could be collected from one or more than one fisher. Thus it may not give the exact information about production capability of the fishers. Nevertheless, data collected directly from the fishers were used to cross check, and the result shows that the reed boat fishers can catch up to 60 kg in good season and not more than 5 kg per day in bad season. On average a fisher can catch 23.4 kg per trip (75-100 birr per trip). The small scale fish traders around Bahir Dar, usually the wives of the fishers, are making an average of 30 birr per day by selling the whole fish directly to the consumers.

On the other hand, a group of fishers working with motor boats rented on a monthly basis, can earn up to a maximum of 3,000 birr per trip. Motor boat fishery operates 24 to 26 days per month.

c) *Employment source*

In many developing countries with absent fisheries management controls in place, the high population pressures and limited employment opportunities increase the attraction of fisheries as a source of employment of last resort. A lot of people living around the lake have engaged in different activities. Traditional reed boat fishery is an easy business to enter and employs the most local people. The fishermen's cooperatives and associations, FPME and other fishery-related activities employ between 3,000-5,000 people.

The average income from fishery-related activities is five times the minimum wage paid by the government, assuming 24 working days per month. A cost-benefit analysis for four types of fishing is presented in Table 4.8.

Table 4.8 Cost benefit analysis of fishing activity for different vessel and gear (Demisse, 2003)

Cost category	**Benzene Motor boat**	**Kerosene Motor boat**	**Reed boat with gillnet modern**	**Reed boat/gillnet traditional**
Costs of boat in birr/boat/year (Rent)	4,800	2,640	167	167
Average No of gillnet per head	21	21	6	5
Costs of total gillnet (birr/year)	4,795	4,795	2,486	780
Cost of fuel and oil (birr/year)	8,671	5,183	0	0
Maintenance cost 10% (birr/year)	960	744	249	78
Crew labor cost (birr/year)	3,598	3,598	1,799	1,799
Other miscellaneous costs (birr/year)	500	500	0	0
Total cost of fishing (birr/year)	**23,345**	**17,460**	**4,707**	**2,829**
Average production kg/year/boat	42,625	39,835	7,301	5,190
Total revenue (birr/year/boat)	**34,953**	**32,665**	**5,987**	**4,256**

4.5 Fishery Policy and Management

It is obvious that the lake fishery can play a significant role in the lives of the fishing communities and contribute to the regional economy if its sustainable yield is maintained. It is crucial, therefore, to design a management plan with clear objectives to utilize the fish resource in a sustainable way. The management objective of the government is to expand the fishery and enhance production. To achieve this objective, a development project was launched 20 years ago that provided lake shore infrastructure, organized workshops, fish landing and cleaning facilities, credit services, etc. The fishery expanded from the support provided by the government. However, given that this resource is open access it is subjected to an influx of fishers.

Recognizing the dangers posed on most water bodies in the country, a National Fisheries Proclamation was ratified by the Federal Parliament in 2003. It provides broad guidelines related to resource conservation, food safety and aquaculture. This document puts considerable emphasis on regulation, permits and the role of the fishery inspector. It is intended that regional administrations should then use the Proclamation as a broad framework upon which their own regulations can be developed.

Amhara was the first region to develop a Regional Fisheries Proclamation, also in 2003. This regional proclamation covers the same areas as the national policy, but has an additional objective relating to the creation of employment opportunities in fishing communities. It also states that information, including research findings, should be made available to the fishing communities. As with the National Proclamation, it relies on regulatory measures (command and control) and the role of the fishery inspector.

The Bureau of Agriculture and Rural Development is mandated to manage the fishery resource. There are many methods available for the management of fisheries, including the use of closed seasons, closed areas, limitation of catches or fishing effort, property rights, taxation, catch quotas and mesh size regulation. Usually, a management regime comprises a mixture of all of these methods, as follows:

a) Gear restriction

The type of gear used in the river and river mouths to catch the spawning stock that results in mass destructive methods (traps, blocking and poisoning) must be banned. It is therefore advisable to use selective fishing gear like gill nets in all fishing grounds of the lake and the rivers.

b) Mesh size regulation

As described in the result, many of the reed boat fishers are using locally hand made traditional gill nets of smaller mesh size than the standard modern gill net mesh sizes used by the motor boats, which will harvest the immature growing stocks. Their mesh size is as low as 6 cm stretched mesh size, which will harvest immature fish of all commercially important species. In order to allow the juvenile fish to grow to full market size, and generate better prices, the smaller mesh sized gillnets (<8 cm stretched mesh) must be restricted and substituted by alternative larger-sized modern gillnets. This can be achieved, for example, through provision of credit to the fishermen. Moreover, monitoring of such cases needs to be implemented to verify whether the mesh-size restriction is applied. For all species fished in Lake Tana, using a combination of different mesh sizes (8 to 12 cm stretched mesh) resulted in better optimal lengths of fish for harvest than using only one mesh size.

c) Area closure and closed season

It is known that both reed boats and motor boats are fishing masses of spawning stock of *Labeobarbus* spp. from river mouths in the rainy season (July to September), which coincides with the peak breeding season. Therefore, location of fishing effort (rivers and 5 km from the river mouths in the lake) and fishing seasons have to be controlled to ensure sustainable utilization of the resource. A closed season should be imposed on fishing in the wetland flooded areas where African catfish breed, ie during the month of July.

d) Control of fishing effort

The measurement of fishing effort in inland fisheries is difficult because there are many small artisanal units rather than a single large craft, and for many, fishing is a part-time occupation. In this context, since absolute effort is difficult to establish, traditional management systems like co-management (local management) are recommended.

e) Co-management

Efficient fisheries management depends not only on the content of the schemes but also on the adherence of fishers to them, and management policies or regulations have little chance of success without the support of various interest groups. Therefore, it is important to set effective regulatory mechanisms for the conservation of the resource and minimization of resource degradation. Lack of awareness and understanding of the value and use of lakes, together with poor public consultation, inadequate stakeholder participation, lack of appropriate and effective governmental institutions and regulation mechanisms are all hindering factors for sustainable utilization of the lake's resources.

4.7 Constraints on Fishing Activity in Lake Tana

Generally the fishery is constrained by lack of sufficient capital to purchase fishing gears and other materials necessary in fish handling and processing. Some of the materials are not available locally in the country. This shortage discourages fishers to use modern fishing gears to boost their production. The relatively high cost of fish caught with motorized vessels, given the recent increases in fuel costs, forces the fishers to concentrate in the southern part of the lake, given its proximity to the markets in Addis Ababa.

The major marketing constraints faced by the fishers are: a) physical access to landing points, collector boat collection points, and road-side traders; b) low fish prices; and c) poor fish handling which affects fish quality (Photo 4.1).

Photo 4.1 Catfish harvest from the ponds in Fogera Woreda, April 2007

Lack of reliable data regarding fishers, fishing gears and potential of fish production from different water bodies is the critical gap to the development of appropriate fisheries management measures. The BoARD, responsible for collection of the above information, has not collected such data for the past 6-7 years. This has made it difficult to show any trend in fish catch, fishing efforts and the fishermen to analyze the resource status and provide timely information for policy makers.

4.7 Major threats

1) Soil erosion: Despite the limited direct human influences on Lake Tana, both wetlands and surrounding catchment areas have already been seriously damaged by man and most of the original forest has disappeared. A number of factors are responsible for the degradation of the catchment, of which population pressure and associated deforestation, cultivation of marginal lands and soil erosion are the most important. The indiscriminate forest clearing, complete removal of crop residue, overgrazing, poor soil management and land use practices further aggravate the situation. Overgrazing of grasslands by livestock is at the moment the most important direct cause for the further degradation of the catchment area. Several soil conservation and reforestation programs are currently carried out by the Government.

2) Use of Wetlands: the littoral region and wetlands of the lake are currently under severe degradation, especially the area covered by papyrus (Teshale *et al*., 2001). Major reasons include the ever growing human population in the wetlands around the lake and the need to increase the food and firewood production for their livelihoods. The local community is harvesting papyrus reed roots during low water level to use as fuel wood. Farmers are cultivating the wetlands when the water is receding.

3) Dam construction: a large dam was constructed in the outflow of the Blue Nile from the lake resulting in increased silt loads and turbidity of lake water and reduced water levels. Water levels of the lake show a strong variation over time, and have been decreasing in recent years. The withdrawal of lake water to generate hydro-electric power combined with the anticipated variations and progressive decrease in rainfall over the years (due to global climate change) are expected to cause severe water level fluctuations and more frequent low water levels in the coming decade. This will also have a negative effect on the wetlands. Fluctuations in water levels and sediment transport will affect biological production in the lake. In addition to the existing dam, five more major dams will be built in the near future for irrigation and power generation in five major tributaries.

4) *Labeobarbus* fishery: the population of endemic *Labeobarbus* species in Lake Tana decreased by 75% over a 10 year period (1991-2001). Fishing during the spawning season (August-September) in river mouths will impact on the survival of river-spawning endemic *Labeobarbus*.

5) Pollution: Bahir Dar is a rapidly growing town, and a 6-fold population increase (to 1,800,000 inhabitants) is expected in the next 50 years. The current practice of discharging untreated industrial and domestic waste into the lake will have adverse effects on the quality of the lake water. Therefore, the construction of a waste water and sewerage treatment plant is urgently needed. There is also pollution from agricultural inputs such as fertilizer, insecticide and herbicides. The use of chemical fertilizer is increasing at the fastest rate.

6) Open access: resource use in the lake is open-access and not regulated. It is important to monitor, control and plan integrated utilization of the resource.

7) Lack of continuous data: The Bureau of Agriculture and Rural Development is responsible to monitor the resource, but due to staff and budget constraints, there are gaps in the data, which constrains provision of sound advice on sustainable utilization of the resource.

8) Inadequate coordination between stakeholders: there are many actors in the Lake Tana sub-basin all operating according to their own interests. In addition, many projects are taking place on the lake, some of which are unknown to the Regional Government. Without formal control systems in place, these activities could cause further depletion of the resource and duplication of efforts.

4.9 Recommendations

1) Continuous data collection systems should be established. Data on fishers, fish catch, fish biology etc will help us to understand the status and trends of the resource. In order to develop appropriate fisheries management, the annual fish production potential must be clearly known. The Bureau of Agriculture and Rural Development in collaboration with Amhara Region Agricultural Research Institute must develop a feasible data collection system.

2) Scientific research on fish biology and its relation to livelihoods in the LTSB should be encouraged. Local and national universities should promote the LTSB as an appropriate research site for both undergraduate and postgraduate studies.

3) Establish Lake Tana Sub-Basin Authority. Lake Tana is a multipurpose lake and has become a source of conflict for the different stakeholders, such as: farmers, fishermen, local inhabitants, authorities, research institutes, and Community Based Organizations (CBOs), NGOs. A platform is required to bring the different stakeholders together and all development activities need to be integrated. A Lake Tana Sub-Basin Authority could serve as a platform and enhance a more harmonious development for the sustainable utilization of the resources.

4) Organising the fishers into a group could help with information dissemination and help to reduce the destructive fishing techniques taking place. Fishers who use destructive fishing gear do so because of their lack of access to modern fishing equipment as well as their ignorance of t the effect on the fish resource.;

5) A management plan for the lake fishery must be developed, including setting closed seasons, ie for rivers and river mouths during the rainy season (July to October) so that breeding stocks will be protected and controlling open access to the lake;

6) Waste disposal needs to be closely monitored and controlled as urban pollution in the southern part of Lake Tana is problematic;

7) The watershed should be actively managed in order to reduce siltation that is a major threat to productivity as well as the longevity of the lake.

8) Wetlands should be protected from degradation by developing wetland conservation and utilization policies as they are breeding and feeding areas for fish. Awareness must be created and action plans developed for the correct conservation of wetlands.

9) Dam construction on rivers should take into account how to minimize their impact on rivers as breeding grounds for migratory fish species.

10) Environmental Impact Assessments must be a pre-requisite to obtaining permission for investment. Any development intervention on the Lake Tana sub-basin needs to consider the possible impact it will have on the ecosystem;

11) Investment in fishery development should be encouraged. The following priority investment opportunities exist:

- Fish processing plant with a capacity of 3,000-4,000 tons at northern side of the lake
- Cage culture on the lake
- Cage culture on reservoirs (Rib, Megech and Gumara Rivers)
- Stocking of fish at the reservoirs
- Land-based pond fish farming
- Aquarium fish (small barbs and Garra)
- Sport fishing (integrate with tourism)

4.11. References

BAFLRC. 2007. Bahir Dar Fisheries and other Aquatic Life Research Center. Unpublished report. Bahir Dar, Ethiopia

Boulenger, G.A. 1905. The distribution of African freshwater fishes. *Nature*, **72 (1869)**: 413-421.

de Graaf M, Dejen E, Sibbing FA and Osse JWM. 2000. The piscivorous barbs of Lake Tana (Ethiopia): major questions on their evolution and exploitation. *Netherlands Journal of Zoology.* 50, 215-223

de Graaf M, Dejen E, Sibbing FA and Osse JWM. 2000. *Barbus tanapelagius*, a new species from Lake Tana (Ethiopia): its morphology and ecology. *Environmental Biology of Fishes* 59, 1-9.

de Graaf M. 2003. Lake Tana's piscivorous *Barbus* (Cyprinidae), Ethiopia. Ecology, Evolution and Exploitation. PhD thesis, Wageningen Institute of Animal Sciences, Wageningen University, The Netherlands, 249 pp.

de Graaf M, Machiels MAM, Wudneh T. and Sibbing FA. 2004. Declining stocks of Lake Tana's endemic *Barbus* species flock (Pisces, Cyprinidae): natural variation or human impact? *Biological Conservation,* 116: 277-287.

de Graaf M, Nentwich ED, Sibbing FA, Osse J.W.M. 2004. Lacustrine spawning: is this a new reproductive strategy among 'large' African cyprinid fishes? *Journal of Fish Biology* 66: 1214-1236.

de Graaf M, H-J Megens, J. Samallo and Sibbing, F.A. 2007. Evolutionary origin of Lake Tana's (Ethiopia) small Barbus species: indications of rapid ecological divergence and speciation. *Animal Biology* 57: 39-48.

Dejen, E. 2003. Ecology and potential for fishery of the small Barbs (Cyprinidae, Teleostei) of Lake Tana, Ethiopia. PhD thesis, Wageningen Institute of Animal Sciences, Wageningen University, The Netherlands, 180 pp.

Dejen E, Vijverberg J, Nagelkerke LAJ, Sibbing F.A. 2004. Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake (L. Tana, Ethiopia). *Hydrobiologia* 513: 39-49.

Dejen, E., J. Vijverberg , M. De Graaf and Sibbing, F.A. 2007. Predicting and testing resource partitioning in a tropical fish assemblage of zooplanktivorous 'barbs': an ecomorphological approach. *J. Fish Biol*. 69: 1356-1378.

Demissie, S. 2003. Socio-economic study on Lake Tana fishery: its role in the livelihood of the fishing community and local people in the region. MSc thesis, The Norwegian Fisheries College of Science, University of Tromso, Norway, 81 pp.

Dgebuadze, Yu. Yu., A.S. Golubtsov, V.N. Mikheev and Mina, M.V. 1994. Four fish species new to the Omo-Turkana basin, with comments on the distribution of *Nemacheilus abyssinicus* (Cypriniformes: Balitoridae) in Ethiopia. *Hydrobiologia* 286: 125-128.

FAO, 1995. Review of the Fisheries and Aquaculture Sector: Ethiopia. FAO, Rome.

FAO, 2003. Fishery country profile, Ethiopia. www.fao.org.

FPME. 2007. Fish Production and Marketing Enterprise, Bahir Dar Branch. Unpublished.

Gasse, F. 1997. Ethiopie et République de Djibouti. In: African wetlands and shallow water bodies. M.J. Burgis and J.J. Symoens (eds.). 300-311.Travaux et documents/Institut Français de Recherche Scientifique pour le Développement en Coopération no. 211 Paris, ORSTOM.

Getahun, A. 2000. Systematic studies of the African species of the genus *Garra*. (Pisces: Cyprinidae). Ph.D. thesis, City University of New York, New York.

Getahun, A, Dejen E & Atenah W. 2008. Fishery studies of Ribb River, Lake Tana Basin, Ethiopia. Final Report. E1573. Volume 2. Addis Ababa, Ethiopia. 126pp.

Getahun, A. and Stiassny, M.L.J. 1998. The freshwater biodiversity crisis: the case of the Ethiopian fish fauna. *SINET: Ethiop. J. Sci*., **21(2)**: 207-230.

Howell, P.P. & Allan, P. 1994. The Nile: Sharing a scarce resource. Cambridge University Press.

Johnson, T.C., Scholz, C.A., Talbot, M.R., Kelts, K., Ricketts, R.D., Ngobi, G., Beuning, K., Semmanda, I. & McGill, J.W. 1996. Late Pleistocene desiccation of Lake Victoria and rapid evolution of cichlid fishes. *Science* 273: 1091-1093.

Lamb, H.F., Bates, C.R., Coombes, P.V., Marschall, M.H., Umer, M., Davies, S.J. & Dejen, E. 2007. Late Pleistocene desiccation of Lake Tana, source of the Blue Nile. *Quaternary Research* 287-299.

LFDP. 1997. Fisheries statistical bulletin number five. Working paper no. 26, Ministry of Agriculture, Addis Ababa, 54 pp.

Mohr, P.A. 1962. *The geology of Ethiopia*. 1-268. University College of Addis Ababa Press, Addis Ababa, Ethiopia.

Molla, M. and Menelik, T. 2004. Environmental Impact Assesment for Unusual Reduced Water Level of Lake Tana. In: Proceedings of the Symposium on Lake Tana watershed management. Lake Net, USA: 35-48.

Muluneh, A.A. 2005. Ecological importance of aquatic macrophytes in the Southern part of Lake Tana. Report of the Amhara National Region Rehabilitation Development Organisation (TIRET).

Nagelkerke, L.A.J. and Sibbing, F.A. 1996. Reproductive segregation among the *Barbus intermedius* complex of Lake Tana, Ethiopia. An example of intralacustrine speciation? *Journal of Fish Biology* 49: 1244-1266.

Nagelkerke, L.A.J., 1997. The barbs of Lake Tana, Ethiopia: morphological diversity and its implications for taxonomy, trophic resource partitioning and fisheries. 296 pp. PhD thesis, Wageningen Institute of Animal Sciences, Wageningen University, The Netherlands,.

Nagelkerke L.A.J. and Sibbing, F.A. 2000. The large barbs (*Barbus* spp., Cyprinidae, Teleostei) of Lake Tana (Ethiopia), with a description of a new species, *Barbus osseensis*. Netherlands Journal of Zoology: **50 (2):** 179-214.

Nichols, J.T. 1928. Fishes from the White Nile collected by the Taylor Expedition of 1927. A discussion of the freshwater fish fauna of Africa. *Amer. Mus. Novit*., **319**:1-7.

Nichols, J.T. and Griscom, L. 1917. Freshwater fishes of the Congo basin obtained by the American Museum Congo Expedition, 1909-1915. *Bull. Amer. Mus. Nat. Hist.,* **37**:739-752.

Palstra A.P., de Graaf M., Sibbing F.A. 2004. Riverine spawning and reproductive segregation in a lacustrine cyprinid species flock, facilitated by homing? *Animal Biology* 54: 393-415.

Roberts, T.R. 1975. Geographical distribution of African freshwater fishes. *Zool. J. Linn. Soc.*, **57**: 249-319.

Rzoska, J. 1976. Lake Tana, headwater of the Blue Nile. In: The Nile, biology of an ancient river. J. Rozaska (ed.). pp 223-232. The Hague, Dr. Junk Publishers.

Sibbing, F.A. and Nagelkerke, L.A.J. 2001. Resource partitioning by Lake Tana barbs predicted from fish morphometrics and prey characteristics. *Reviews in Fish Biology and Fisheries* **10:** 393-437.

Teshale, B., R. Lee & Zawdie, G. 2001. Development initiatives and challenges for sustainable resource management and livelihood in the Lake Tana region of Northern Ethiopia. In Proceedings of the wetland awareness creation and activity identification workshop in Amhara National Regional State. January 23 rd 2001 Bahir Dar, Ethiopia. Dixon, A. B., A. Hailu & A. P. Wood (eds.). pp 33-43.

Tewab, D. 2005. Benthic community on the Northern part of Lake Tana. Unpublished report.

Wonde, A., Seyoum, M., J. Vijverberg, Dejen, E. 2007. Seasonal and spatial variations in primary production of a large tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and turbidity. *Aquatic Ecology.***41:**195-207.

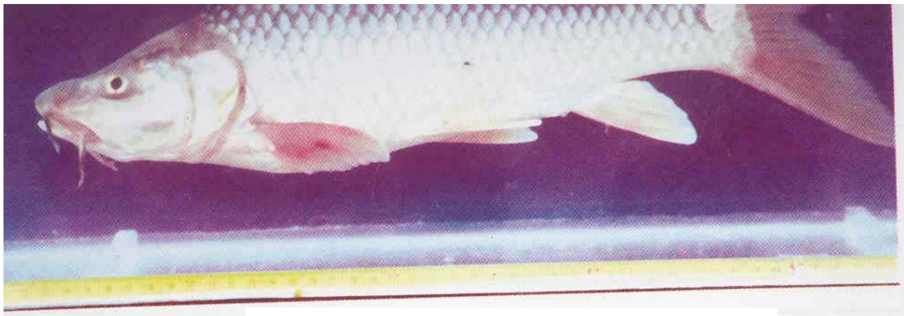
Wudneh, T., 1998. Biology and management of fish stocks in Bahir Dar Gulf, Ethiopia. PhD thesis, Wageningen Institute of Animal Sciences, Wageningen University, The Netherlands, 143 pp.

4.12 THE FISHES OF LAKE TANA

Labeobarbus intermedius

Labeobarbus acutirostris

Labeobarbus brevicephalus



Labeobarbus crassibarbis

Labeobarbus daineilli

Labeobarbus gorgorensis

Labeobarbus gorgori

Labeobarbus longissimus

Labeobarbus macropthalmus

Labeobarbus megastoma

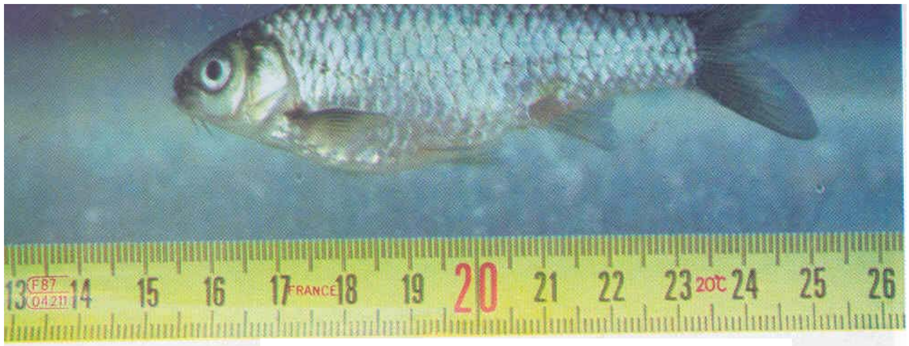
Labeobarbus nedgia

Labeobarbus platydorsus

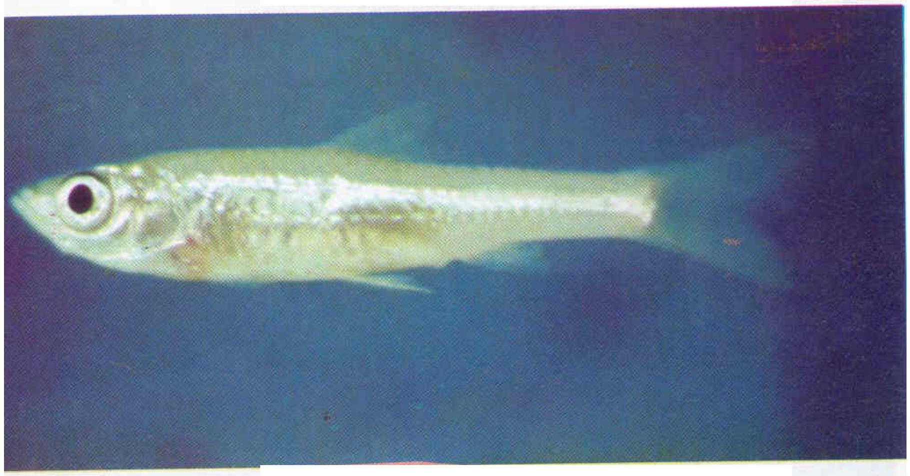
Labeobarbus surkis

Labeobarbus truttiforms

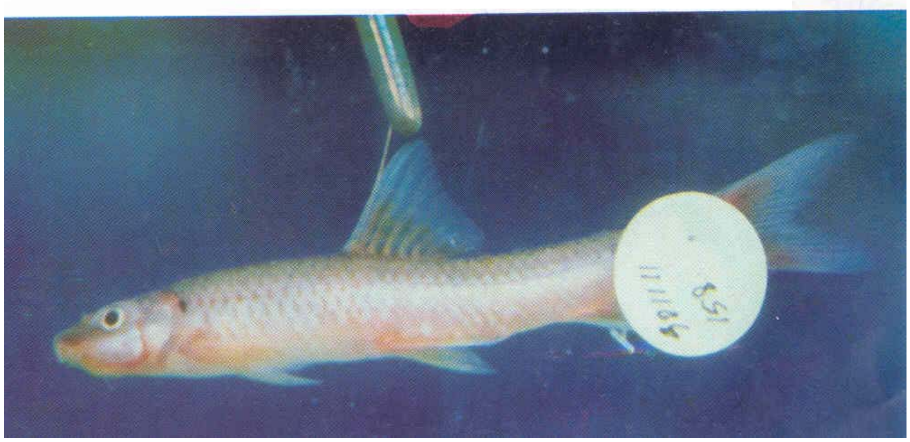
Labeobarbus tsanensis



Barbus humilis

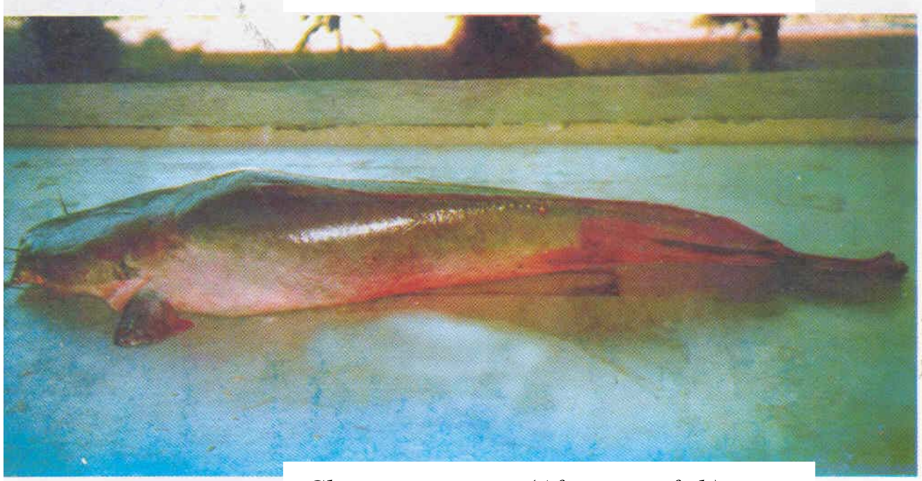


Barbus tanapelagius



Garra tana

Oreochromis niloticus (Tilapia)



Claris gariepinus (African catfish)

Varicorhinus beso (Beso)