THE DECLINE OF THE LAKE TANA (ETHIOPIA) FISHERIES: CAUSES AND POSSIBLE SOLUTIONS

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THE DECLINE OF THE LAKE TANA (ETHIOPIA) FISHERIES: CAUSES AND POSSIBLE SOLUTIONS

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ABSTRACT

This article reviews major findings of a vast body of scientific studies on the ecology of the fish community and the fisheries in Lake Tana over the past 25 years. There are three commercially important fish taxa in the lake: Nile tilapia, African catfish and *Labeobarbus* spp. The catch per unit of effort for all the three taxa declined during the last two decades: total catch 177 kg/trip in 1993,140 kg/trip in 2001 and 56 kg/trip in 2010. But the most drastic reduction was observed for the *Labeobarbus* species: 63 kg/trip in 1993, 28 kg/trip in 2001 and only 6 kg/trip in 2010. Most probably, both recruitment overfishing and increased recession farming contributed to the decline. The migrating *Labeobarbus* spp. were heavily affected by irrigation and dam constructions causing destruction of breeding and nursery habitats in the spawning rivers. We conclude that implementation of the fisheries legislation gazetted in 2003 and the lake management plan adopted in 2015 is crucial to prevent the collapse of the Lake Tana fishery. Suspended silt from erosion and land degradation, caused by deforestation in the catchment, increased the turbidity of the lake water. The current Maximum Sustainable Yield is approximately 10-20 kg $ha^{-1} \cdot yr^{-1}$, which is low compared to other African lakes. The low productivity seems to be caused both by both light limitation and nutrient limitation. Soil erosion is probably limiting primary production. Appropriate land use management and soil conservation around Lake Tana, such as afforestation and implementing zero-grazing practices, are urgently needed.

KEYWORDS: land use; biosphere reserve; maximum sustainable yield; Nile tilapia; *Labeobarbus*

INTRODUCTION

Until recently, fish was not highly valued by Ethiopians as a source of animal protein. Before 1980s the average per capita annual fish consumption by Ethiopians was only 0.1 kg (de Graaf, 2003). As a result the fishery in Ethiopia is one of the poorest developed sectors of the economy. Prior to mid 1980s, the fisheries in Lake Tana consisted of predominantly subsistence reed boat fishery, operated by the Negada-Woito ethnic group. Absence of motorized boats restricted the fishers' mobility to the shore areas of the lake. The fishers used locally made fish traps, hooks and small gillnets (15-20m, 8-10cm stretched mesh), mainly targeting Nile tilapia (de Graaf *et al*., 2006). Modern fishing gears, such as motorized boats and nylon twine gillnets, were introduced in 1986 by the Lake Tana Fisheries Resources Development Program. This project was launched by the Dutch Non Governmental Organization (NGO), Interchurch Foundation Ethiopia, (ISE-Urk), to assist the poor fishers around the Southern Gulf area and on the nearby Islands by improving fishing technologies and supplying modern fishing gears (Nagelkerke, 1997; Wudneh, 1998). This enabled the fishers to exploit offshore and distant river mouths in the north-eastern part of the lake, which resulted in an increase of fish catches. Furthermore, in order to improve storage and marketing facilities, the Fish Production and Marketing Enterprise (FPME) was established in Bahir Dar Town. Almost all the fish catch landed in the Bahir Dar area is purchased, processed and transported to Addis Ababa by the FPME (de Graaf *et al*., 2006). The three main species groups targeted by current fisheries are a species flock of endemic large *Labeobarbus* spp., *Clarias gariepinus* Burchell (African catfish) and *Oreochromis niloticus* Linnaeus (Nile tilapia).

From the three taxa targeted by the fishers, the endemic *Labeobarbus* spp. are the most vulnerable to fisheries because of their annual migration from the lake to the tributary rivers for spawning. The commercial gillnet fishery on *Labeobarbus* spp. is highly seasonal and mainly targets the spawning aggregations. More than 50% of the annual catch is obtained in the river mouths during August and September (Nagelkerke *et al*., 1995; Wudneh, 1998, de Graaf *et al*., 2005; de Graaf *et al*., 2006). The strong decline in the proportion of juvenile fish of the riverine spawning labeobarbs is most likely partially the result of this practice (de Graaf *et al*., 2004; de Graaf *et al*., 2006).

Deforestation, especially in the second half of the previous century, resulted in erosion and land degradation in the lake catchment area (Mekonnen *et al*., 2015) and there is an urgent need to solve the high soil erosion rates (Gessesse *et al*., 2016). Inflowing rivers carry heavy loads of suspended silt into the lake, thereby increasing the turbidity of the lake water and reducing the primary production (Wondie *et al*., 2007). Since phytoplankton production is the basis of the food web, this most likely also affected the higher tropic levels, and thus the fish production.

The catch per unit effort for all the three fish taxa of commercial interest declined during the last two decades, but the most drastic reduction was observed for the *Labeobarbus* species. In this review we focus on the potential reasons of this decline and investigate to what extent management options and legislations may mitigate the present poor state of the fisheries in Lake Tana.

This review summarizes the most important results of fisheries and fish ecological studies on Lake Tana of the past 25 years. Employing a holistic view, it also explores the underlying factors affecting its productivity. This review is mainly based on published scientific papers from cooperative studies carried out by researchers from Wageningen University (Netherlands), Bahir Dar University (Ethiopia), Addis Ababa University (Ethiopia) and the Amhara Region

Agricultural Research Institute (ARARI). We have structured the review as follows: study area, primary productivity and carrying capacity for fish harvest, fish-food organisms, fish community, fisheries, threats to the fisheries, and fisheries management and legislation.

RESULTS

Study Area

Lake Tana is situated in the north-western highlands of Ethiopia (12°N, 37°15'E) on a basaltic plateau at an altitude of 1830 m and covers an area of ca. 3050 km^2. It is the source of the Blue Nile River (Great Abbay), with a catchment area of ca. 16 500 km^2. Seven permanent and more than 40 small seasonal rivers feed the lake with water. The Blue Nile is the only outflowing river.

The climate of Lake Tana is characterised by four seasons: A main-rainy season with heavy rains during July-September, a post-rainy season during October-November, a dry season during December-April and a pre-rainy season during May-June. In the lake, dissolved oxygen concentration (range: 6.4-7.2 mg l^{-1}) and temperature (range: 22.5-23.5 ^oC) vary seasonally only within narrow limits. Conductivity was lowest in the main-rainy season (average: 142 μ S cm^{-1}) and highest in dry and pre-rainy seasons (average: 182-184 μ S cm^{-1}); range calculated over a 20 months period (Wondie *et al*., 2007).

Lake Tana is shallow (average depth 8 m, maximum depth 14 m) and oligotrophic-mesotrophic. Its water column does not experience any lengthy period of thermal stratification

(Dejen *et al*., 2004). Annual soil loss in the Lake Tana catchment is high (Shimelis *et al*., 2009). Inflowing rivers carry a heavy silt load into the lake during the rainy season. The suspended sediments reduce the underwater light intensity and as such the primary production of Lake Tana (Wondie *et al*., 2007).

Bahir Dar, located on the southern border of the lake, is a Regional capital with ca. 260 000 inhabitants. Around the lake and its catchment, including the town of Bahir Dar, live about two million people. The area around the lake has been cultivated for centuries. This lake and adjacent wetlands provide directly and indirectly a livelihood for more than 500 000 people.

Extensive wetlands, of which Fogera and Dembia floodplains are the largest, jointly comprise ca. 65% of the lake's catchment area (Figure 1). These wetlands are the largest in the country and form an integral part of the complex Tana-ecosystem. During the rainy period these wetlands are hydrologically connected with the lake. They act as nurseries for most fish populations in the lake, and serve as breeding ground for water fowl and mammals. The diversity of birds is especially high (Atnafu *et al*., 2011).

Primary Production and Carrying Capacity for Sustainable Fish Harvest

The lake is characterised by a low water transparency due to high silt load of the inflowing rivers during the rainy seasons (May-November) and daily resuspension of sediments in the inshore zone. Earlier studies found no relation between chlorophyll-a content and water transparency, which might suggest that water transparency is mainly controlled by suspended sediments rather than by phytoplankton biomass. The mean chlorophyll-a concentration varied seasonally and ranged from 2.6-8.5 mg m^{-3} (mean: 4.5 mg m^{-3}) in the offshore zone (Wondie *et al*., 2007).

Measurements of primary productivity during different seasons over two years indicate that the gross primary production in the open water in Lake Tana was relatively low (Wondie *et al*., 2007). The highest production rates were observed in the post-rainy season (Oct –Nov) which coincided with a bloom of *Microcystis* and higher chlorophyll-a levels. This seasonal high production is very likely caused by the sediment run-offs in the rainy season resulting in higher nutrient inputs. It is also the season in which the water is most turbid due to extensive sediment run-off during the rains and might be an indication for light limitation. These conditions favoured *Microcystis* spp. (Cyanobacteria) which through its buoyancy have an advantage over other algae (Wondie *et al*., 2007).

The gross primary production rates of Lake Tana are among the lowest compared with other tropical lakes (Wondie *et al*., 2007). The relationship between sediment concentration, water transparency and nutrient availability is complicated. In general, the two main reasons for the lower productivities in turbid waters are the absorption of nutrients on the suspended clay particles, making them less available for phytoplankton, and the reduction of the depth of the euphotic zone (Grobbelaar, 1983). Therefore, suspended silt can have both a direct and an indirect negative effect on the primary production. Thus although primary production in Lake Tana seems to be limited by nutrient availability, the elevated sediment concentration might also an important limiting factor.

A rough estimate of the total maximum sustainable fish yield (MSY) was made based on estimates of the gross primary production in the open water of Lake Tana (average 2.4 g O_2 m^{-2}), using the predictive regression model given by Melack (1976) for nine African lakes (for more information about this approach see Downing *et al*., 1990). On basis of the average primary production the estimated possible yield would be ca. 10 $kg \cdot ha^{-1} \cdot yr^{-1}$. However, the real MSY will probably be lower. Firstly, because ca. 80% of the total annual fish production (ca. 27 $kg \cdot ha^{-1} \cdot yr^{-1}$), is represented by two *Barbus* spp. that are not utilized by the fisheries (Wudneh, 1998; Dejen *et al*., 2006; Dejen *et al*., 2009).

Secondly, independent estimate of MSY can be made based on the total fish production. The total fish production in the lake was estimated to be 93 kg wet weight ha^{-1} yr^{-1} of which 53 kg wet weight ha^{-1} yr^{-1} was realised by the two *Barbus* spp. (Wudneh, 1998; Dejen *et al*., 2009). The MSY for the whole fish community was estimated on the basis of this production estimate using the equation given by Sparre & Venema (1998). MSY for the whole fish community was estimated to be 18.6 kg wet weight ha^{-1} yr^{-1} of which 10.6 kg wet weight ha^{-1} yr^{-1} was the potential MSY of the two *Barbus* spp. Therefore, on basis of the fish production the estimated MSY for the whole fish community of Lake Tana is approximately 20 $kg \cdot ha^{-1} \cdot yr^{-1}$, but this estimates also includes the small barbs, which are currently not targeted by the fishery. If we exclude the *Barbus* spp. the estimated MSY is ca. 10 $kg \cdot ha^{-1} \cdot yr^{-1}$which is low compared to other African lakes (Melack, 1976; Jul-Larson *et al*., 2003).

Fish-food organisms

Zooplankton organisms are the dominant secondary producers in Lake Tana (Dejen *et al*., 2004). Approximately half of the numbers encountered were copepods and the other half cladocerans. The calanoid copepod *Thermodiaptomus galebi lacustris,* which is endemic to the Lake Tana catchment, dominated the zooplankton community. Of the cladocerans two daphnia species, *Daphnia hyalina* and *D. lumholtzi* are common.

The zooplankton community structure of Lake Tana is unusual for tropical lakes because of its relatively high proportion of temperate species, i.e. *D. hyalina*, and *Ceriodaphnia dubia* (Dejen *et al*., 2004). This can likely be attributed to the relatively low water temperatures of Lake Tana due to its high altitude. Significant temporal differences in copepod and cladoceran abundance were observed, with the highest overall zooplankton density in the dry season (Dejen *et al*., 2004).

Macrobenthic invertebrates such as oligochaetes, *Chaoborus* spp. and chironomids, show low densities both inshore and offshore (Jacobus Vijverberg, unpublished). In contrast the microbenthic ostracods show relatively high densities in the inshore zone (4 000-60 000 ind m^{-2}), but are lacking in the offshore area of the lake. The low densities of benthic invertebrates may be caused by the low content of organic matter in the bottom substrates, which consists of volcanic basalts usually covered with a soft substratum transported by the inflowing rivers. Density and biomass of macrofauna in the macrophyte beds are relatively high, but these beds are limited to the littoral zone (ca. 10% of lake surface area).

Fish Community

Twenty one of the 28 fish species in Lake Tana are endemic to the Lake Tana catchment (Table I). This speciation could occur because the lake maintained its isolation from the lower Blue Nile basin by 40 m high falls, 30 km downstream from the Blue Nile outflow (Sibbing *et al*., 1998). Although the lake was formed ca. 5 million years ago by lava blocking of the Blue Nile, the lake dried up several times. The last drying event occurred 10 000–15 000 years ago, thus the endemic fish species are not older than 15 000 years (Lamb *et al*., 2007).

The most species-rich fish family in the lake are the cyprinids, represented by four genera: *Barbus*, *Garra*, *Labeobarbus* and *Varicorhinus*. The genus *Garra* is represented by four species, *G. dembecha* Getahun and Stiassny, *G. dembeensis* (Rüppell) and two endemic species, *G. regressus* Getahun and Stiassny and *G. tana* Getahun and Stiassny (Stiassny& Getahun, 2007). All four species are algivorous. *Varicorhinus* is represented by a single species *V. beso* Rüppell which scrapes algae from substrates.

Fifteen large (max. 82 cm fork length, FL) labeobarbs (*Labeobarbus* spp.) belong to a unique species flock of endemic cyprinids (Nagelkerke *et al*., 1994; Nagelkerke & Sibbing, 2000; Nagelkerke *et al*., 2015). The cyprinid fish community also contains, furthermore, three small (<11 cm FL) barbs: *Barbus humilis* Boulenger, *B. pleurogramma* Boulenger and *B. tanapelagius* de Graaf, Dejen, Sibbing & Osse (Boulenger) (de Graaf *et al*., 2000). The latter two species are endemic to the Lake Tana catchment. *Barbus humilis* is mainly present in the shallow inshore zone, whereas *B. tanapelagius* is common in the large pelagic zone of the lake. *Barbus pleurogramma* is mainly present in the wetlands around the lake.The three *Barbus* spp., feed on zooplankton (Dejen *et al*., 2006; Vijverberg *et al*., 2014), with *B. tanapelagius* being the only obligate zooplanktivore since the other species utilise also other animal food items. *Barbus pleurogramma* maintains the most benthivorous diet, whereas *B. humilis,* juvenile labeobarbs and *Labeobarbus brevicephalus* (Nagelkerke & Sibbing) feed for ca. half (by biovolume) of their diet on zooplankton and for the other half on adult floating insects, insect larvae and benthic invertebrates. *Barbus tanapelagius* and the adults of *L. Brevicephalus* are the only zooplanktivores occupying the large offshore zone (Dejen *et al*., 2006).

Several studies showed that nine *Labeobarbus* species, *L. acutirostris* (Bini)*, L. brevicephalus, L. intermedius* (Rüppell)*, L. macrophtalmus* (Bini)*, L. megastoma (*Nagelkerke &

Sibbing), *L. nedgia* (Rüppell), *L. platydorsus* (Nagelkerke & Sibbing), *L. truttiformis* (Nagelkerke & Sibbing) and *L. tsanensis* (Nagelkerke & Sibbing), ascend more than 50 km up tributary rivers for reproduction during the main rainy season. They spawn in fast flowing, clear, well oxygenated gravel beds of the tributary streams (reviewed by Anteneh *et al*., 2012a). Age 0+ juveniles of the migratory riverine spawning *Labeobarbus* species stay in the pools of the rivers near the spawning area until the following rainy season (Anteneh *et al*., 2013a).

There is only one cichlid, *O. niloticus* (Nile tilapia), which is predominantly an herbivore, feeding on macrophytes, algae and detritus. The catfish family (Clariidae) is represented by a single species, *C. gariepinus* (African catfish). This species is an omnivore, feeding mainly on zooplankton (Vijverberg *et al*., 2014).

Fish diet studies based on gut content analyses collected during multiple months over two years show that most fish species relied directly or indirectly on zooplankton (Nagelkerke, 1997; de Graaf *et al*., 2003; Dejen *et al*., 2006). The zooplankton production was estimated from calculated biomass and published annual P/B ratios (accumulated production over 12 months divided by the average biomass over the same period). Assuming a 10% trophic efficiency, and a dry: fresh weight ratio of 1:5 for fish, this resulted in an estimated potential zooplanktivorous fish production of 185 kg $ha^{-1.}$ $year^{-1}$. Since the total small barb production was estimated to be only 52.9 kg fresh wt $ha^{-1.}$ $year^{-1}$, this means that *Barbus* spp. only consume a small proportion (about 29%) of the total zooplankton production (Dejen *et al*., 2009). They are not utilizing calanoid copepods, which represent ca. 57% of the zooplankton production and it is likely that because of this the *Barbus* production was food limited (Dejen *et al*., 2009). It is estimated that piscivorous labeobarbs consumed about 56% of the *Barbus* production annually. But additionally many bird species were also preying on them (Nagelkerke, 1997). Therefore, limitation of *Barbus* production by predation during certain periods in the year is likely.

Eight species of the fifteen endemic *Labeobarbus* species are piscivorous, four are obligate piscivorous and four others are facultative piscivores (Sibbing & Nagelkerke, 2001; de Graaf *et al*., 2003). The main prey items eaten and matching their optimal prey size 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.

The Fisheries

Currently, there are both reed boat and motorised gillnet fishery in Lake Tana. About 80% of the fishers use reed boats and the remaining 20% have motorized boats for fishing (Gebremedhin *et al*., 2013). In order to compensate the declining commercial catch, the fishers sharply increased their fishing effort. The number of motorized boats increased from 5 in 2000 to 80 in 2010 (Mohammed *et al*., 2013), and the number of reed boats from 400 in 2000 to 1500 in 2010 (de Graaf *et al*., 2004; Mohammed *et al*., 2013). Before 2000, fishers had been using multifilament gillnets, but the much more efficient monofilament gillnets are currently used most often. The total number of gillnets used increased steeply, in 2011 ca. 20 times more gillnets were set than in 2001 (Mohammed *et al*., 2013; Gebremedhin *et al*., 2013).

It is difficult to estimate the total fish catch for the whole of Lake Tana because of the many fish landing places around the lake. Therefore, we present here only the annual trends in catch per unit effort (CPUE). We defined the CPUE as the total daily catch in kg per motorized boat. In order to reduce bias the daily catch was standardized for the average number of gillnets carried per trip (22.21 gill nets). Total fish catch per unit effort was 177 kg/trip in 1993, 140 kg/trip in 2001 and 56 kg/trip in 2010. The catch per unit effort for all the three commercially important fish taxa declined during the last two decades, but the decline was most severe for the endemic *Labeobarbus* spp. flock and African catfish (Table II). The average catch per unit effort for the endemic *Labeobarbus* spp. flock was 62 kg/trip in 1993, 28 kg/trip in 2001 and 6 kg/trip in 2010. Catch per unit effort for African catfish was 67 kg/trip in 1993, 36 kg/trip in 2001 and 8 kg/trip in 2010.

Threats to the Fisheries

Lake siltation due to extensive deforestation

Land degradation due to severe deforestation and land erosion in the Lake Tana catchment area has increased dramatically, especially in the second half of last century (Genet, 2011). Due to scanty vegetation and high rainfall during short periods in the main rainy season, the soil loss rate from areas around the lake is high (30-65 tonnes ha^{-1} yr^{-1}) and substantially increased during recent years. Soil loss rates are especially high in the eastern part of the lake, i.e. 5-250 tonnes ha^{-1} yr^{-1}, and lowest on the western side of the lake (Shimelis *et al*., 2001; Teshale, 2003). In 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 which may have a negative effect on lake productivity (Wondie *et al*., 2007).

Changes in agricultural practices

Recently, a shift in farming practices took place in the highlands of Ethiopia. In the earlier centuries farming occupied upland of the mountain areas, but in the last two decades with increasing population pressure and limitation of land and water, farming moved to wetlands including shorelines of lakes and river banks (Atnafu *et al*., 2011). This was also the case in the Lake Tana catchment (Wondie, 2010). When the lake level drops during the dry season hundreds of km^2 of dry lake area becomes available for agriculture and is used by farmers to grow crops. The wetlands around the southern Bay of Bahir Dar alone cover ca. 1170 km^2. These wetlands have water for ca. 4 months and it is the country's largest rice production area. Farming practices, such as, drainage and water diversions for small irrigations resulted in soil erosion and loss of soil fertility (Yitaferu *et al*., 2004). Socio-economic studies showed that Fogera land owners adjoining the wetlands follow the water retreat and farm until the land dries up completely (Atnafu *et al*., 2011). Farmers often cultivate the shore area of the lake by deforesting even to the extent of burning macrophytes (Wondie, 2010). This results in loss of spawning grounds for the fish inhabiting the lake.

Because of water abstraction for irrigation, in many tributary rivers of Lake Tana the pools became disconnected during April and May, which has severe consequences for the downstream migration of 0+ juveniles of *Labeobarbus* spp. to the lake (Anteneh *et al*., 2013a).

In addition, also a decline in juvenile labeobarb abundance in the pool habitats of Gumara River, a major tributary of Lake Tana, has been recorded after the river was disconnected from the lake due to excessive water abstraction from the river for small scale irrigation (Anteneh *et al*., 2013a). This suggests high juvenile mortality caused by desiccation of pools. Unsustainable farming of the riparian areas of the inflowing rivers has become very common in the Lake Tana region (Atnafu *et al*., 2011).

Dam Construction

The Ethiopian government considers the Lake Tana region to have a high potential for economic growth, mainly because of its important water resources. Mega hydropower and irrigation dam construction projects are underway in almost all tributary rivers of Lake Tana (Figure 1). It is expected that these dams will further impede the migratory riverine spawning of *Labeobarbus* species (Anteneh *et al*., 2013b). Moreover, these dams will result in a reduction of water flow in the downstream adjacent floodplains causing insufficient inundation of downstream spawning areas of African catfish and Nile tilapia (Getahun *et al*., 2008; Anteneh *et al*., 2012b).

Illegal fishing gear

Currently, almost all fishers use undersized (5 to 7 cm) stretched mesh size monofilament gillnets (Tewabe, 2013). This illegal fishing gear was introduced from 2008 onwards from Sudan. The fishers strongly prefer monofilament to multifilament gillnets since they are twice to four times as efficient as multifilament nets (Faife, 2003).

Water Hyacinth infestation

The shore macrohabitats of Lake Tana became infested by water hyacinth (*Eichhornia crassipes*) since 2011. This noxious weed expanded quickly after its introduction to the northern, north-eastern and north-western shores of the lake and covered more than 40 km of the shoreline after less than two years. Currently, the water hyacinth vegetation covers ca. 34 500 ha which corresponds to more than one-third of the shoreline (ca. 128 km) (Anteneh *et al*., 2014; Anteneh *et al*., 2015) (Figure 2). Preliminary studies show that juvenile fishes prefer shores covered by indigenous macrophytes and avoid water hyacinth infested areas (Anteneh *et al*., 2015). Water hyacinth has also impacted the surrounding human communities around the lake and its catchment by reducing fish catches and decreasing available landing sites (Wassie Anteneh personal observations).

Fisheries Management and Legislation

The Federal Fish Resource Development and Utilization Proclamation 315/2003 is the legal framework for fisheries management in Ethiopia (Federal Democratic Republic of Ethiopia, 2003). The proclamation is intended to conserve fish biodiversity and its environment as well as to prevent and control over-exploitation of the fisheries resources. It includes management measures in the catchment to protect the fisheries.

The Amhara Region was the first region to develop a Regional Fisheries Proclamation (ANRS, 2003). Detailed enforcement proclamation was adopted by the regional government, the Amhara National Regional State Fisheries Resource Development Protection and Utilization Proclamation Enforcement in 2007 (ANRS, 2007). The Bureau of Agriculture is given legal responsibility to issue directives necessary for the full implementation of the proclamation and regulation. The Bureau has completed drafts of two directives (BoA, 2010a, b), but so far these have not been implemented. The regional government is highly concerned by the decline of the fish stock and also fishers have been asking the government to take measures. Accordingly, a team of experts was assigned to develop the Lake Tana fisheries management plan including enforcement of the proclamations.

Fisheries management plan

The Fisheries Management Plan for Lake Tana has been developed and adopted by the local government on September 2015 (Dejen *et al*., 2015). The management plan includes among others the implementation of the following points: issue of directives, licensing of commercial fishers**,** closed seasons and areas, gear restrictions**,** mesh size regulations**,** training of fisheries inspectors, and setting up a data collection and monitoring system. The Bureau of Agriculture (BoA) should issue the two directives as soon as possible. Any commercial fishing unit, such as boats, should be licensed. A license commits the fishers to respect the fishery regulations and fishery inspectors should control if the fishers obey these regulations.

To promote fish recruitment, it is important to reduce the fishing pressure on the breeding populations. To achieve this, fishing in the inflowing rivers of Lake Tana and five km of the river mouths will be closed for fishing every year from July to October. Wetlands around Lake Tana like Welala and Shesher will be closed from any fishing activities during the rainy season. The whole Lake Tana will be closed every year for any fishing activities for two months (June and July). Destructive fishing such as poisoning, explosives, fishing practices that can hinder the free movement of spawning stocks on spawning migrations such as fencing the rivers, seines, monofilament and trawls will be forbidden. Mesh size (stretched mesh) of gill nets for fishing will be limited to 8 cm and above, allowing immature fish to escape.

Currently, there is no standard data collection and monitoring system available. Many reports are contradicting and questionable. In the management plan detailed data collection, reporting and monitoring systems are outlined.

CONCLUSIONS

The Maximum Sustainable Yield (MSY) for Lake Tana is approximately 10-20 $kg \cdot ha^{-1} \cdot yr^{-1}$, which is low compared to other African lakes. The low productivity seems to be caused both by light limitation and nutrient limitation. Soil erosion is probably limiting primary production and this problem will become even more important in the future where the degree of soil erosion is increasing at an alarming rate. Appropriate land use management and soil conservation around Lake Tana, such as afforestation and implementing zero-grazing practices, are urgently needed. During the last two decades the total catch per unit of effort for *Labeobarbus s*pp. was reduced to ca. 10%. This decline was mainly the combined result of recruitment overfishing, the use of illegal fishing gear and the destruction of breeding and nursery habitats in the spawning rivers by dam constructions and irrigation schemes. To prevent the collapse of the Lake Tana fishery it is crucial that the existing legislation and management plan is enforced and adopted by the local government and that management measures in the Lake Tana catchment are implemented to prevent further degradation of the Lake Tana fisheries.

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Table I. The fish species of Lake Tana, their taxonomic group, maximum length (Fork Length, cm), relative abundance, food and habitat. * = endemic to Lake Tana catchment. Data from Nagelkerke & Sibbing (2000), De Graaf *et al*. (2006), Dejen *et al*. (2006) and Vijverberg (unpublished). Habitats refer to: benthic= predominantly present near the bottom in the lower part of the water column, pelagic= predominantly present in upper part of the water column, littoral= inshore with or without macrophytes (0-4 m deep), sublittoral= inshore without macrophytes (4-8 m deep), offshore= open water (8-14 m deep). (Modified after Vijverberg *et al*., 2009).

Family	**Species**	**Max. Length (FL, cm)**	**Abundance**	**Food**	**Habitat**
Balitoridae	*Nemacheilus abyssinicus*	3.6	Rare	Algae	Benthic
Cichlidae	*O. niloticus*	40	Common	Macrophytes, algae-detritus	Pelagic, littoral, sublittoral
Clariidae	*C. gariepinus*	70	Common	Fish, zooplankton, benthic invertebrates, algae	Pelagic, littoral, sublittoral
Cyprinidae	*B. tanapelagius**	8.9	Common	Zooplankton	Pelagic, sublittoral, offshore
	B. humilis	9.6	Common	Zooplankton, benthic invertebrates	Benthic, littoral, sublittoral
	*B. pleurogramma**	4.0	Common	Benthic	Benthic, wetlands,

			invertebrates	flood planes
G. dembecha	17.0	Common	Algae	Benthic
G. dembeensis	12.0	Rare	Algae	Benthic
*G. regressus**	13.5	Common	Algae	Benthic
*G. tana**	12.0	Common	Algae	Benthic
Labeobarbus acutirostris*	41	Common	Fish	Benthic, inshore
*L. brevicephalus**	32	Common	Zooplankton, adult insects	Pelagic, sublittoral, offshore
*L. crassibarbus**	51	Common	Detritus, benthic invertebrates	Benthic, sublittoral, offshore
*L. dainellii**	49	Occasional	Fish	Littoral
*L. gorgorensis**	62	Occasional	Benthic invertebrates, bivalves	Pelagic, littoral, sublittoral, offshore
*L. gorguari**	53	Occasional	Fish	Littoral
L. intermedius	49	Common	Benthic invertebrates, gastropods, macrophytes	Benthic, littoral
*L. longissimus**	61	Occasional	Fish	Pelagic, littoral, sublittoral
*L. macrophtalmus**	43	Common	Fish, benthic invertebrates, detritus	Pelagic, sublittoral, offshore

*L. megastoma**	82	Common	Fish	Pelagic, littoral, sublittoral, offshore
*L. nedgia**	71	Common	Insect larvae, benthic invertebrates	Benthic, littoral
*L. osseensis**	29	Rare	Adult insects, macrophytes	Littoral
*L. platydorsus**	64	Common	Fish, insect larvae, molluscs, detritus	Benthic, sublittoral, offshore
*L. surkis**	43	Occasional	Macrophytes, algae, benthic invertebrates	Pelagic, sublittoral
*L. truttiformis**	44	Occasional	Fish	Pelagic, sublittoral, offshore
*L. tsanensis**	39	Common	Insect larvae, gastropods, benthic invertebrates	Benthic, sublittoral, offshore
Varicorhinus beso	36	Common	Benthic algae	Benthic, littoral

Table II. Average daily catch of *O. niloticus*, *Labeobarbus* spp. and *C. gariepinus* of the motorized commercial fishery in Lake Tana in 1991-1993 (Wudneh, 1998), 2001 (de Graaf *et al*., 2006) and 2010-2011 (Mohammed *et al*., 2012, 2013). Catch per unit effort in kg per boat trip (percentages between brackets).

Taxa	Average daily catch in kg per boat trip (percentage)		
	1991-1993	2001	2010-2011
O. niloticus	47.8 (27)	75.6 (54)	42.2 (75)
Labeobarbus spp.	62.0 (35)	28.0 (20)	6.1 (11)
C. gariepinus	67.3 (38)	36.4 (26)	7.8 (14)
Total	177 (100)	140 (100)	56 (100)

List of Figures

Figure 1

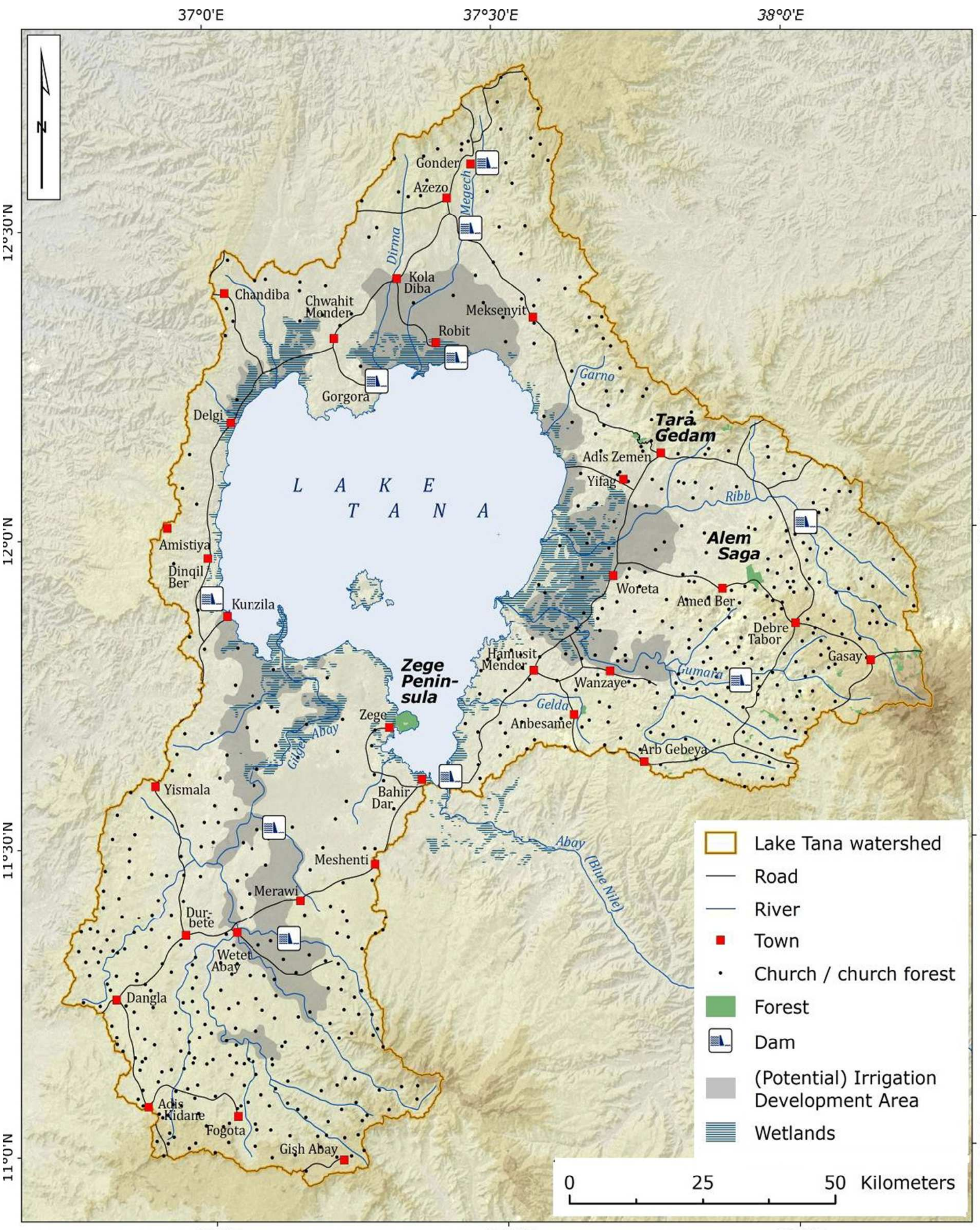
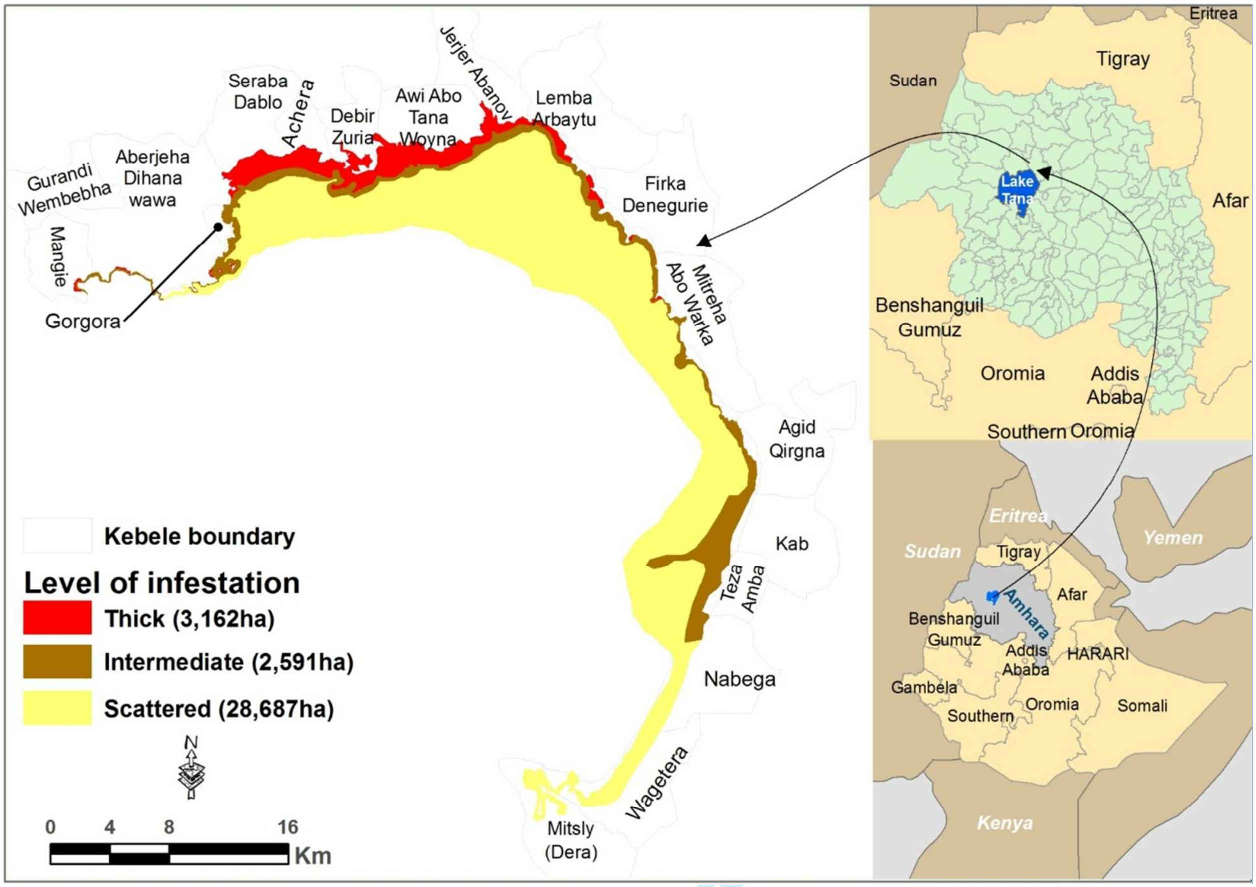

37°0'E
37°30'E
38°0'E
12°30'N
12°0'N
11°30'N
11°0'N
N
LAKE TANA
Gonder
Azezo
Megech
Dirma
Chandiba
Chwahit Monder
Kola Diba
Meksenyit
Robit
Gorgora
Garno
Delgi
Tara Gedam
Adis Zemen
Yifag
Ribb
Alem Saga
Amistiya
Dinqil Ber
Kunzila
Woreta
Amed Ber
Debre Tabor
Gasay
Hamusit Mender
Wanzaye
Gumara
Zege Penin-sula
Zege
Gelda
Anbesame
Gilgel Abay
Arb Gebeya
Bahir Dar
Yismala
Meshenti
Abay
(Blue Nile)
Merawi
Dur-bete
Wetet Abay
Dangla
Adis Kidane
Fogota
Gish Abay
Lake Tana watershed
Road
River
Town
Church / church forest
Forest
Dam
(Potential) Irrigation Development Area
Wetlands
0 25 50 Kilometers

Figure 2.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Achera
Debir Zuria
Awi Abo Tana Woyna
Jerjer Abanov
Lemba Arbaytu
Gurandi Wembebha
Aberjeha Dihana wawa
Firka Denegurie
Mangie
Gorgora
Mitreha Abo Warka
Agid Qirgna
Kab
Teza Amba
Nabega
Wagetera
Mitsly (Dera)
Kebele boundary
Level of infestation
Thick (3,162ha)
Intermediate (2,591ha)
Scattered (28,687ha)
N
0 4 8 16
Km
Eritrea
Tigray
Sudan
Lake Tana
Afar
Benshanguil Gumuz
Oromia
Addis Ababa
Southern
Oromia
Eritrea
Sudan
Tigray
Yemen
Amhara
Afar
Benshanguil Gumuz
Addis Ababa
HARARI
Gambela
Southern
Oromia
Somali
Kenya