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LAKE VICTORIA AND THE COMMON PROPERTY DEBATE: IS THE TRAGEDY OF THE COMMONS A THREAT TO ITS FUTURE?

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Abstract

Lake Victoria is the largest among the African Great Lakes in East African region that are believed to have both dynamic and fragile aquatic ecosystems. Within two decades, the lake has experienced extensive resource exploitation leading to constrained productivity and drastic decline of native biodiversity. Intensive non-selective fishing, catchment vegetation degradation, industrial and agricultural pollution, the introduction of exotic species and uneven patchwork of governmental laws are some of the reasons for the current ecological woes facing Lake Victoria. This paper intends to stimulate recognition of Lake Victoria and its catchment as a lived *Commons*, to be shared, protected, managed and enjoyed by all who live around it. The paper compares the original biodiversity status of the lake with the current status and discusses the role of unlimited access as a function of the loss of the Lake's biological wealth. The Lake's water resource base, fishery, wetlands and other aquatic resources have been exhaustively discussed. In this review, we uphold the Hardin's school of thought that freedom of the commoners causes resource overuse leading to poverty. Therefore, limiting freedom could be essential. However, there is need for provision of alternative means of survival since people with no choices would continue over-exploiting ecosystems even under limited access. The Lake Victoria basin commons should be protected by strict legal and clear political framework based on public trust doctrine, reinforced in law that the Lake is vital for the survival of people, plants and animals living on or near it and therefore must be protected for the common good. The political jurisdictions should consider governing the Lake basin as one integrated watershed. It is our fervent hope that bordering communities will secure grass root movements to protect and nurture Lake Victoria and its environs for the benefit of the present and future generations.

Keywords: The Lake Victoria, Commons, Tragedy, Biodiversity, Freedom

1. INTRODUCTION

1.1 General overview of Lake Victoria

With a total catchment area of 250,000 Km^2, of which 68,000 km^2 is the actual lake's surface area, Lake Victoria is the largest freshwater lake in Africa and worlds' second largest (LVBC, 2011). The Lake, which is located in the upper reaches of the Nile River Basin, lies astride of the equator between latitude 2.5°S and 1.5°N, and longitude 32° and 35°E (Figure 1). The lake is shared by three East African countries in varying proportions: Kenya (6%), Uganda (43%) and Tanzania (51%). Other countries such as Rwanda and Burundi are within upper watershed that drains into the Lake Victoria through river Kagera (Swallow *et al.*, 2003). According to seismic reflection profiles, the Lake Victoria, which originated as a result of regional tectonic tilting, is estimated to be 400,000 years old (Johnson *et al*., 2000). Lake Victoria arose from a dry landscape 14,600 calendar years ago (14.6 ka) with an extremely high primary production in it's first 500 years, thanks to high input of nutrients from the flooded surrounding landscapes (Kendal, 1969; Johnson, 1993; Johnson *et al*., 2000). The relationship between the changing water quality, sediment properties of the lake and the beginning of rapid expansion of human population and agricultural activity in 1970s (Verschuren *et al*., 2002) forms the subject of this article.

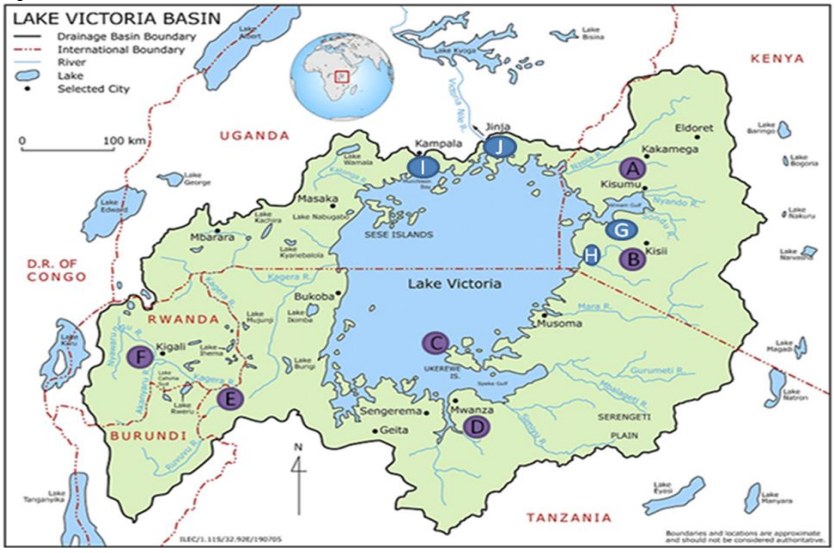

Figure 1: Lake Victoria, boardering countires and the entire catchment area including major towns found within the catchment area (A: Kisumu, B: Kisii, C: Ukerewe island D: Mwanza, E: Butare, F: Kigali, G: Homabay, H: Migori, I: Kampala and J: Jinja)

The Lake Victoria is a treasured natural resource in the larger Eastern African region as it supports the livelihoods of about 30 million people directly or indirectly (World Bank, 1996; Odada *et al*., 2006). The region has experienced rapid urbanization over the recent past with the towns concentrated along the lake's edge growing at rates far in excess of the regional average of 3% per year (World Bank, 1996; EAC, 2008). The urbanization process in the East African countries has increased under the impact of several factors including rural poverty that has stimulated rural-urban migration and land pressures (Abila, 2000). The Lake is heavily utilized for fisheries, transportation, tourism, water supply and waste disposal (EAC, 2008).

1.2 The tragedy of the commons: the case of Lake Victoria

The term *Tragedy of the Commons* was first described by Garret Hardin in 1968 who affirmed that "the inherent logic of the commons remorselessly generates tragedy". This tragedy is a dilemma arising from the situation in which individuals, driven independently by the power of their own self-interests, ultimately deplete a shared limited resource without considering future sustainability of the same resource (Dietz *et al*., 2003). In fact, they even forget that there livelihood depends on the sustainability of the resources in question and this fuels more tragedy. The word *tragedy* refers to the depletion of the limited resources while *commons* stands for inclusive ownership suggesting the absence of private ownership and property rights of the resource in question (Hillman, 2002). This statement precisely describes the present situation of biodiversity status in the Lake Victoria basin. This paper aims at outlining the current effects of the tragedy of the commons which has resulted in the depletion of Lake Victoria fish and non-fish stocks, destruction of the riparian eco-system and deterioration of water quality. According to McCarthy (2002), most fish stocks in community waters are below their safe biological limits for stock biomass. Lake Victoria fish stocks have by tradition been regarded as "common goods" and therefore have been treated as common properties of the riparian communities (Onyango, 2000; 2004). In the absence of clear cut and strictly followed rules of engagement, common property resources are subject to economic problems such as overexploitation, which usually results in biological damage to the ecosystem. Over six decades ago, Gordon (1954) declared that overfishing and the resulting depletion of future fish stock is a type of negative externality that can be easily referred to as the *Tragedy of the Commons*. Indeed, overfishing in Lake Victoria is one of the major

issues that have been widely discussed in both the past and recent literatures (Kendall, 1969; Ogutu-Ohwayo, 1990; Jansen, 1997; Matsuishi *et al*., 2006; Kolding *et al.,* 2008; LVBC, 2011).

Several authors agree that indeed unlimited access whether in the grazing grounds or fishery would inevitably ruin the commons thus becoming a perfect recipe for creating human misery (Onyango, 2000; Jentoft *et al*., 2010). In his own words, Hardin (1968, 1998) argued in a much cited quote that "freedom in commons brings ruin to all." This is consistent with bio-economic modeling of human behaviour in open access fisheries of Gordon (1954). This statement has inspired researchers and practitioners alike to believe that limiting the freedom of access and operation in the fishery commons is the key to sustainable resource management and poverty alleviation among small-scale fishers around the world (Geheb *et al*., 2007; Béné *et al*., 2010). Other scientists have argued that the root cause of the tragedy of the commons in most of biological ecosystems is the restriction of freedom rather than unlimited freedom (Jentoft *et al*., 2010). There a divergence in opinion as to whether people who do not have other means of survival except fishing for their livelihood, in an over-exploited ecosystem, could be regarded as being "free". In fact they are likely to continue exploiting the resource even if they derive nothing out of it. In this regard, Jentoft *et al*. (2010) thought that alleviating poverty among resource users calls for a broader concept of freedom than the Hardin's theory. In his own words, Sen (1999) said "Freedoms are not only the primary ends of development, they are also among its principal means". Anyhow, the authors would not wish to be wholly trapped into this un-ending philosophical debate but rather to specifically discuss the systematic degradation of Lake Victoria's biological wealth in the merciless hands of freedom of access.

In Lake Victoria situation, fish stock sizes, catches and landings in beaches have drastically declined within the last two decades and many species are close to extinction (Twong'o & Sikoyo, 2004; Odada *et al*. 2006). Destructive fishing gears are used in fish harvesting, which severely harms the lakes ecosystem and fish habitats (Njiru *et al*., 2005; 2006). For years, the expansion of Lake Victoria fisheries encouraged fishermen to exploit fish resources in an unsustainable manner (Yongo *et al*., 2005). The growing demand for fish has led to an increase in prices such that even the local communities including fishermen cannot afford to buy freshly landed fish. Under such conditions, every fisherman strives to maximise his / her benefit oblivious to the damages caused to the future fisheries stock. Consequently local communities around Lake Victoria are left insecure with regard to food security (Abila, 2000; Odongkara *et al*., 2005). Geheb *et*

al. (2007) attributed the food insecurity and malnutrition experienced among many fisher folks to unrestricted fish trade because substantial quantities of fish is sold to more economically rewarding markets.

1.3 The unsustainable fishing pressure in Lake Victoria fishery

In the year 2000, the Lake Victoria Fisheries Organization (LVFO) commissioned a coordinated survey on the entire Lake Victoria to determine the level of the lake's fishing effort. The findings of the survey revealed the severity of fishing pressure exerted on the Lake Victoria fishery. A total of 1,493 landing sites were reported along the 3,450 km lake shoreline, translating to one landing site in every 2.3 km of shoreline (LVFRP, 2001; LVEMP, 2003; LVFO, 2008a, 2008b). Up to 129,328 fishermen using 42,548 fishing crafts including variety of fishing gears such as beach seines, scoop nets, *dagaa* seines, cast nets, long line hooks, hand line hooks, traps and mosquito nets were reported (LVEMP, 2003) (Table 1). Indeed, the Nyanza gulf is the most intensively fished part of the lake with more than10 fishermen per km^2 compared to about 2 per km^2 in the rest of the lake (LVFO, 2008c). Overall, Lake Victoria fisheries like other regulated access fisheries show significant signs of over-exploitation, overcapitalization and low profitability (Bokea & Ikiara, 2000). This decline in fish stocks threatens the survival of nearly half a million communities in Kenya who depend on the lakes fishery (Yongo *et al.*, 2009).

Table 1: Detailed classification of human fishing pressure in the three bordering countries of Lake Victoria

Country	Landing sites	Landing site (%)	Shore line (Km)	Rate (landing site)	Fishermen	Crafts	Gill nets
Uganda	597	40	1,750	1 every 3km	38341 (29.7%)	15,544	291,398
Tanzania	599	40	1,150	1 every 2km	56,060 (43.3%)	15,489	225,803
Kenya	297	20	550	1 every 2km	36,159 (27%)	11,515	128,973

(Adapted from LVBC, 2011)

1.4 Implications of the 'commons' concept in Lake Victoria's biological wealth

Water resource base and pollution

As Hecky (1993) rightly said, 'we are indeed fortunate that the Lake Victoria received the attention of some excellent limnologists and fisheries

scientists in the 1950's and 1960's so that we have perspective on the lake's modern condition'. Indeed, based on the earlier publications we can compare, contrast and appreciate the systematic changes that have so far occurred in the Lake Victoria biological ecosystem. In early 1950s, the lake seemed a giant reservoir of enormous ecological stability, far too large to succumb to the impacts of human activities around it (Cohen *et al*., 1996). Indeed the lake was thought to be immuned from the water crisis that threatens other world waters. The water quality of Lake Victoria ecosystem has consistently degenerated since early 1960s (Hecky, 1993; Sitoki *et al.*, 2010). Today, the biological health of the lake has become an increasing concern as residents watch their shorelines recede (Obiero *et al.,* 2012) and beaches closed due to fisheries decline (Verschuren *et al*., 2002). The lake derives its waters largely from rivers draining from the surrounding catchment and precipitation. However, the quality of water in Lake Victoria has probably been taken for granted by many stakeholders (Twongo & Sikoyo, 2004). Human population outburst, their associated activities and economic development as well as foreign fish introductions, have caused the systematic degradation of water quality in the lake (Okungu *et al*., 2005). Such anthropogenic factors include: water pollution, siltation, eutrophication and water-related public health problems in the larger Lake Victoria basin (Okungu *et al*., 2005; EAC, 2008). The Lake Victoria has thus been turned into a free dumping site for all kinds of domestic and industrial wastes. This has only been worsened by the reluctant and weak legislations currently at the central government and municipal councils of towns bordering the lake (Ntiba *et al*., 2001).

The land based activities play major roles in the lake water quality issues while the lake based activities are only secondary (Okungu *et al*., 2005). Through soil erosion, fertilizers used in agricultural lands have found access into the lake waters leading to increased nitrogen and phosphorus levels (World Bank, 1996). Precisely, pollution loading due to urban waste water runoff and soil erosion from Kenya, Uganda and Tanzania is estimated at 3,505 tons yr^{-1} and 1,624 tons yr^{-1} of total nitrogen and total phosphorus respectively (COWI, 2002). Pollution loading from industrial activities stand at 414 tons yr^{-1} of total nitrogen and 342 tons yr^{-1} of total phosphorus while pollution loading from rivers is 49,509 and 5,693 tons yr^{-1} of total nitrogen and total phosphorus respectively (COWI, 2002). Other human induced pollution sources include transport waste and direct contamination of the lake water by human activities on the shore line. The cumulative impacts of these activities are now clearly evidenced as Lake Victoria shows various signs of severe environmental distress, including depleted oxygen levels, eutrophication and reduced transparency (Hecky,

1993; Hecky *et al*., 1994; Hecky *et al.,* 2010). Inflow of residues from the use of chemical herbicides and pesticides in some areas in the Lake Catchment and specialized industries such as gold mining are also potential sources of heavy metal and pesticide pollution (Henry & Kishimba, 2002; Musa *et al*., 2011). Massive algal blooms including the potentially toxic blue green algae variety have been reported in Lake Victoria (Ochumba & Kibaara, 1989; Hecky *et al.,* 2010). The lake water transparency has declined from 5 m in the early 1930s to 1m or less by early 1990s while water borne diseases also increasing considerably (COWI, 2002).

Within a period of 20 years, the water weeds in Lake Victoria have grown incredibly fast. The exotic water hyacinth (*Eichhornia crassipes)* has proved to be the biggest menance in the lake in some places extending out from the shore in a mat of vegetation as far as the eye can see contributing to a fast decline of the ecosystem's health and fish populations (Howard & Matindi, 1998; Kudhongania & Chitamwebwa, 1995; Mugidde *et al*., 2005).

2. FISHERY AND FISH BIODIVERSITY

Before introduction of foreign fish species in Lake Victoria in early 1960s, the traditional fish fauna and fishery of the Lake Victoria was dominated by Cichlids (Graham, 1929). Two tilapia species (*Oreochromis esculentus* and *Oreochromis variabilis*) and other fishes like *Bagrus docmac* and *Labeo victorianus* were the main source of the Lake Victoria fishery (Figure 2 and Table 2) (LVFS, 1958; Kudhongania & Chitamwebwa, 1995). The aesthetic biological beauty of the lake was even boosted further through the explosive speciation of haplochromines, which created about 300 species dominating the itchthiofauna of the Lake Victoria (Greenwood, 1974; Lowe-McConnell, 1975; Kaufman, 1992; Goldsmidt & Witte, 1992; Kaufman *et al*., 1997; Barlirwa *et al*., 2003). At the beginning of the 20th century, the lake was sparsely fished using a variety of simple traditional methods such as basket traps, hooks and seine netting made out of papyrus, which were fairly sustainable (Graham, 1929). Twongo and Sikoyo (2004) observed that even though there were signs of deforestation along riparian forests, human occupancy was relatively low and much of the shoreline was covered by extensive riparian wetlands. At this time, the lake's biological ecosystem was ecologically well balanced thanks to the high trophic efficiencies of a variety of native fishes at that time (Ogutu-Ohwayo, 1990). The environmental condition of the lake was undisturbed and pristine perhaps due to limited access of the people.

Due to increased human occupancy of the Lake Victoria basin, intensive fishing began, the lake's shoreline started to shrink as most wetlands were cleared for agricultural fields and settlements (Balirwa, 1998). The subsequent expansions of towns and cities bordering the Lake Victoria and population boom through massive rural to urban migrations created enormous demand for Lake Victoria fisheries leading to declines of fish supply (Abila, 2000; Yongo *et al*., 2005).

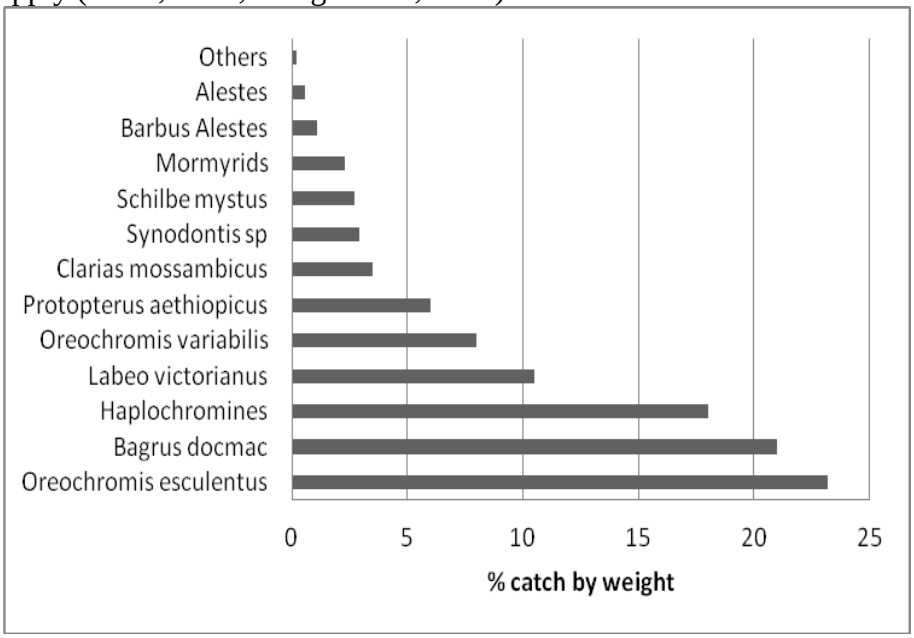

Figure 2: Major commercial fish species from Lake Victoria in 1958 (as % age of catch by weight) (Adapted from Kudhongania & Chitamwebwa, 1995)

Table 2: Annual summary of fish species found in landings (gill net data) for Lake Victoria at recording stations in Kenya, Uganda, and Tanzania in 1957

Species	**Percentage of total catch (by number)**		
	Kenya (7 stations)	**Uganda (10 stations)**	**Tanzania (16 stations)**
Oreochromis esculentus	46.7	52.5	18.0
Oreochromis variabilis	14.9	20.2	3.9
Haplochromines	2.6	1.9	12.7
Labeo victorianus	14.7	2.4	31.9
Bagrus docmak	8.0	9.0	15.9
Barbus altianalis radcliffi	1.5	1.3	0.5

Major fishery

Mormyrus spp.	6.0	3.7	3.3
Clarias gariepinus	1.5	1.8	0.9
Schilbe intermedius	2.4	0.2	4.7
Brycinus jacksonii	1.1	5.8	2.6
Synodontis spp.	0.1	0.2	4.8
Protopterus aethiopicus	0.5	1.0	0.5
Other species	0.0	0.0	0.2

*(*Adapted from LVFS, 1958)

2.1 Impacts of Nile perch (*Lates niloticus*) introduction in Lake Victoria

There is no conclusive evidence to suggest that the Nile perch entry into the Lake Victoria was as a result of unlimited access policy that prevailed at that time (Pringle, 2005). However, the authors hold that this school of thought could also be genuine. Together with alien Nile perch, four other alien tilapiines (*Oreochromis niloticus*, *Monochromes leucostictus*, *Oreochromis melanopleura* and *Tilapia zillii*) were introduced into the Lake Victoria between 1950 and 1960 (Twongo & Sikoyo, 2004). However, it is the impact of Nile perch (*L. niloticus*) in Lake Victoria that has generated debate among ecologists and social economists almost in sharply contrasting dimensions. The Nile perch was introduced into Lake Victoria to boost the fishing economy (Twongo & Sikoyo, 2004) and also for sport fishing purposes (Ogutu-Ohwayo, 2004; Pringle, 2005). At that time, there were heated disputes about the possible costs and benefits of such introductions (Fryer, 1960; Anderson, 1961). Whereas the environmental ecologists condemned the act, social economists praised and supported it (Lowe-McConnell, 2009). Since 1970s, the issue of introduction of non-native species in lakes has consistently formed subject of discussion among various scientific communities with a general concurrence that non-native species introductions threaten the existence of local biodiversity in any biological ecosystem and should be handled with caution (Vitule *et al.*, 2006, 2009; Zimmerman & Vondracek, 2006; Gozlan 2008). However, this school of thought is only popular among environmental ecologists and evolutionary biologists (Pringle, 2005; Lowe-McConnell, 2009). The introductions took the advantage of research gaps and limited knowledge concerning ecological behaviour of Nile perch. In future, such introductions should be guided with informed scientific studies.

Nile perch is an alien introduction that has made considerable impacts on both the ecological and socio-economic interests of the Lake Victoria (Pringle, 2005). The growth of the Nile perch fishery in Lake Victoria was rightly hailed as a positive socio-economic development, even being termed as an 'economic saviour' (Gibbon, 1997; Matsuishi *et al*., 2006; Balirwa, 2007). Indeed, the fact that Lake Victoria supported a multi-million dollar commercial Nile perch fishery (Njiru *et al.,* 2008) and the markets for its fisheries products increased in the international domain was a clear indication that Nile perch was the economic saviour for the fishermen. Today, the negative impacts attributed to the deliberate introduction are obvious ecological realities (Gozlan, 2008). Nile perch eliminated endemic species of haplochromines, whose trophic diversity (phytoplanktivores, detritivores, zooplanktivores, insectivores, molluscivores, piscivores and egg-eaters) contributed to high trophic efficiency, ecological balance and environmental quality in the Lake Victoria (Payne, 1987; Barel *et al*., 1985; Witte *et al*., 1992, 2007; Goldsmidt *et al*., 1993; Kudhongania & Chitamwebwa, 1995). Indeed, eradication of haplochromines created accumulation of phytobiomass and detritus leading to enhanced oxygen deficits (Mugidde, 1993; Seehausen *et al.,* 1997; Okungu *et al*., 2005; Balirwa, 2007). The intense decomposition of the phytobiomass has caused serious oxygen deficits in near shore bays and Gulfs such Murchison, Napoleon, Winam and Mwanza, which are some of the most productive spots in the Lake Victoria (Mugidde *et al.,* 2005). Through Nile perch competitive displacement, some of the native fishes such as *O. esculentus*, previously a fish of great commercial importance virtually disappeared from the main lake but moved to little satellite lakes like Kayugi, which have large proportions of diatoms in their phytoplankton (Goldsmidt *et al*., 1993; Witte *et al*., 1992; Goudsward *et al*., 2002; Balirwa, 2007). Riverine native fishes such as *Labeo* sp., *Bagrus* sp., *Barbus* sp., *Clarias* sp., *Protopterus* sp. and *Schilbe* sp. occur in Lake Victoria only in small populations close to the river inflows and outflows (Table 3) (Ogari & Dadzie, 1988). It is likely that many other biotas such as aquatic insects, crustaceans and plant species have been affected by the radically altered trophic structures in the lake. This however requires in depth scientific investigations. It is disturbing that such an enormous biodiversity can perish in such a relatively short time due to uneven patchwork of governmental laws that favours free access policy. The once multi-species rich Lake Victoria fishery has gradually lost her fish biodiversity glory over the years leading to dominance by only three species currently (Nile perch, Nile tilapia and a native sardine (*Rastronobela argentia)* (Ntiba *et al*., 2001; Balirwa *et al.,* 2003). See table 3. The authors

confess that the drastically reduced taxonomic and trophic diversity coupled with the deteriorating water quality situation and riparian vegetation in the Lake Victoria make predictions on the long-term sustainability of the fishery more difficult. In this regard clear political frame-work based on public trust doctrine and focused research is essential in all the neighbouring countries.

Table 3: Catch (in metric tons) for the Ugandan waters of Lake Victoria for four time periods

Taxa	1966 -1967	1976 -1977	1986 -1987	2000
Lates	4	500	58809	72632
Tilapiines	17747	2480	5772	30530
Bagrus	6646	4645	8173	152
Mormyrus	486	130	156	443
Clarias	2237	1620	655	69
Protopterus	2627	2035	309	469
Barbus	813	330	85	0
Synodontis	122	305	28	127
Haplochromines	1955	1280	3	4
Brycinus	223	0	0	0
Labeo	204	20	0	0
Rastrineobola	0	5	1001	70333
Others	41	0	7	17

For 1966 -1967, 1976 -1977, and 1986 -1987, the values represent the average of the 2 years. Tilapiines were mainly *Oreochromis esculentus* and *Oreochromis variabilis* in 1966 – 967, mainly *Oreochromis niloticus* in 1976 -1977 and exclusively *O. niloticus* thereafter. (Adapted from LVFRP, 2001 and Muhoozi, 2003)

In addition to native fish extinction problems associated with Nile perch introductions (Pringle, 2005); new scientific revelations indicate that anthropogenic factors, such as overfishing, pollution and eutrophication are fuelling the menace (Goudsward & Wanink 1994; Seehausen *et al.,* 1997; Verschuren *et al.,* 2002; Kolding *et al.,* 2008). Indeed, excessive and destructive fishing pressure exerted by the use of under sized meshes, beach seines, poison and dynamite is often enhanced by greed for money, lack of sense of ownership of the fishery created mostly by the 'open access policy' syndrome (Cohen *et al*., 1996; Koldong *et al*., 2008). Nevertheless, other factors including insufficient research information on fish stocks and poverty also play major roles in terms of destructive fishing. It is not an

overstatement therefore to declare that destructive fishing pressure steadily assaults and degrades the biological resource base of the Lake Victoria fishery including spawning, nursery and feeding habitats. This also has a prolonged effect on the fish reproductive and recruitment potential. If not arrested, this can lead to eventual fish stocks decline and total collapsed fishery. This is the scenario that is currently present in the Lake Victoria fisheries. The chief causes of overfishing are the propensity for use of 'illegal' gears (below recommended or legal mesh sizes of 5''), indiscriminate gears, outlawed fishing techniques and mass-target fishing methods (Abila, 2002; Geheb *et al.*, 2007).

Ntiba *et al*. (2001) observed that fisheries in Lake Victoria are free and unrestricted; anyone can make or buy a vessel and start fishing. The lake fisheries is also characterized as a regulated open access fishery, which means that participants are free to enter, subject to regulations like gear restrictions, area closer and seasonal restrictions (Eggert & Ellegård, 2003). Hence, the ability of fisheries institutions to create a positive incentive structure is undermined by the complex nature of fishing and the fact that enforcement often is difficult to exercise (Eggert & Lokina, 2008). Fishermen often question the results of stock assessment surveys and maintain that there is more fish in the lake than biologists can count (Van Marlen, 1991). They often express their opinion that the fish in the lake can never be finished and wonder why the government is restricting the exploitation of a resource freely given by God the almighty (Ikiara, 1999). Of course the problem seems to have been enhanced by difficulty to harmonize different political laws and surveillance logistics governing the giant water resource. The political jurisdictions should consider governing the Lake basin as one integrated watershed to attain sustainable level of fishing and some level of control.

3. WETLAND RESOURCES

Wetlands are important components of the natural ecosystems, with significant functions and values for the human environment and socioeconomic development due to their rich biodiversity. Wetlands support a diversity of aquatic animals including micro-crustaceans, shrimps, crayfish, insects, pond snails, tadpoles, frogs, birds and fish (Owino, 1979). These organisms are crucial components of wetland ecosystems, providing credible food web linkages between plants, microorganisms and other animals (Richardson, 1994; Balirwa, 1998). Wetland resources of Lake Victoria include floodplain and fringing emergent macrophytes often

dominated by papyrus (*Cyperus papyrus*) (Gichuki, 2003). Near-shore wetlands of Lake Victoria were a heaven for a variety of biodiversity including encrusted algae, submerged and floating macrophytes, macro-invertebrates, and fishes formed the beauty of the pristine riparian zones of the lake (Gichuki, 2003). These zones acted as feeding, refuge and spawning sites for variety of native fishes in the lake (Okedi *et al*., 2005). The emergent wetlands of Lake Victoria regulated the flow of water through their spongy underwater biomass contributing to water conservation, retained incoming sediments and nutrients and also acted as habitats for fish refuge (Owino, 1979; Balirwa, 1998; Gichuki, 2003; Okedi *et al*., 2005).

Despite, the enormous ecological and biological roles of wetlands to the Lake Victoria ecosystem, wetland degradation in the region is not a new subject. The conversion and unsustainable use of wetland resources of Lake Victoria is always human induced emanating from free access policies. People have exploited the emergent wetland plants such as papyrus for traditional building materials, mat and basket making (Gichuki, 2003). Floodplain wetland zones are being used for grazing livestock especially during the dry season while large tracks of wetlands are being converted for agriculture and industrial development; diary and rice and vegetable farming (LVBC, 2011; Obiero *et al.*, 2012). The near shore wetlands are not spared either. Destructive fishing practices such as the use of boat seines are known to destroy macrophytes, which are fish nurseries. At the end of it all, the efficiency of wetlands as natural guardians of Lake Victoria against nutrient enrichment and siltation has been severely compromised (LVBC, 2011).

4. THE AQUATIC INVERTEBRATE COMMUNITIES IN THE LAKE VICTORIA

Scientific evidence has shown that uncontrolled human induced activities have not spared the aquatic invertebrate communities in the lake either. Comparison of historical and current zooplankton data indicates changes in dominance from the large bodied *Calanoids* and *Cladocerans* to smaller sized *Cyclopoids* (Figure 3*)* (Worthington, 1931; Rzoska, 1956; Mwebaza-Ndawula *et al*., 2003). Some important zooplankton species e.g. *Ceriodaphnia dubia* and *Simocephalus vetulus*, which were abundant during mid 1950s, appear to have become extinct (Rzoska, 1956; Okedi, 1990). The lake's sediment core analysis of Mwebaza-Ndawula *et al*. (2003) also revealed significant decline of two *Cladoceran* groups: *Bosmina longirostris* and *Chydorids sp.* Nevertheless, Ndawula *et al*. (1999) observed that molluscs have increased following the near extinction of

mollusc eating haplochromine fishes in the lake. Indeed, other authors have also noted the high diversity of molluscs especially based on huge amounts of mollusc shells, which are frequently deposited along the lake shores by wave actions (Mwambugu, 2004).

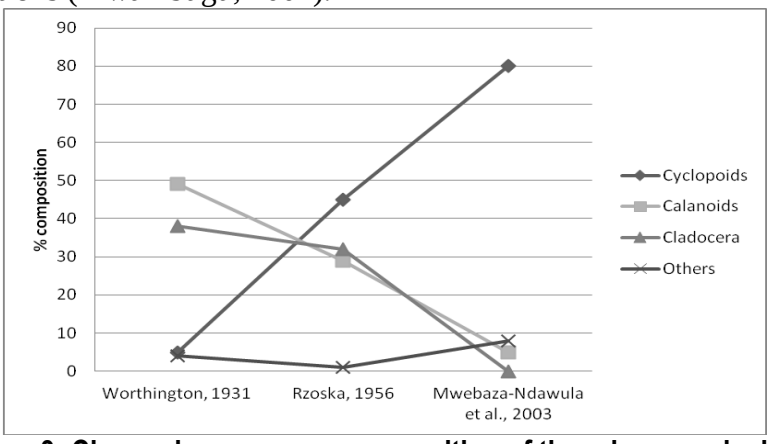

Figure 3: Change in percenage composition of three key zooplankton taxonomic groups at an open station in Northern Lake Victoria between the 1930s and 1990s.

The changes in vertebrate abundance and diversity in the lake are associated with corresponding human induced alterations in environmental conditions including eutrophication, pollution anoxia and shifts in fish communities (Ogutu-Ohwayo, 1990; Okedi, 1990). Ogari and Dadzie (1988) were even more specific that Nile perch diet changes with increasing size. They observed that young Nile perch preyed mostly on invertebrates such as crustaceans while large immature Nile perch supplemented the invertebrate diet with both young and small fish especially after the decline of their preferred prey (haplochromines). Studies on Lake Victoria's aquatic invertebrates have many challenges such as lack of sufficient historical information and taxonomic skills leading to limited publications (LVBC, 2011).

5. NON-FISH VERTEBRATE COMMUNITIES IN THE LAKE VICTORIA BASIN

The Lake Victoria Basin harbours a diversity of non-fish vertebrates e.g. amphibians, reptiles, birds and mammals, which are known to be of direct and indirect values to humanity. Studies have shown that each of these taxa have different levels of dependency on the aquatic habitat (Ojok,

1990). While some species require the aquatic ecosystems and its constituent habitats for most of their life cycles, others such as birds are occasional visitors (Byaruhanga & Nalwanga, 2006). However, published information on historical species richness and abundance of reptiles and amphibians in the Lake Victoria basin are scanty indicating that limited studies have been done despite their importance as biological indicators of ecosystem health in the land-water ecotones of Lake Victoria. On the contrary, birds have received sufficient attention of researchers (Byaruhanga & Nalwanga, 2006). The lake basin has experienced increased human population and subsequent activities, which have proved harmful to the survival of aquatic and semi aquatic fauna. Dam construction, fish factories, farming, building of beaches and other infrastructural developments are on the increase along the shores and within the basin impacting flora and fauna of the region in different ways (LVBC, 2011). Byaruhanga (2003) exposed how uncontrolled human activities threaten the existence of Lurembe bay in Uganda, which is an important bird area. Birds have suffered from drowning and getting entangled in fishing nets, poaching, loss of feeding roosting and breeding grounds through wetland destructions (LVBC, 2011). Nevertheless, high mobility of birds enables them to fly away from unfavourable environments inflicted by human interference. This could be the reason why the population and diversity of avifauna have declined in the recent years.

6. MANAGEMENT OPTIONS FOR LAKE VICTORIA AND ITS ENVIRONS

Lake Victoria management is a subject that has been widely discussed in many local and international scientific forums. However, no significant improvement can be confidently reported at least by considering the current ecological condition of the Lake Victoria. Many authors have indeed put forward valuable management strategies, which if implemented strictly, positive significant changes would be observed (Ntiba *et al*., 2001; Njiru *et al*., 2005, 2008; Chapman *et al*., 2008). Ntiba *et al*. (2001) reported lack of an integrated management plan for Lake Victoria basin and varying laws and regulations among riparian states as major management challenges. Njiru *et al*. (2005, 2008) emphasised on ecosystem approaches, genuine stakeholder involvement and provision of alternative livelihoods. Other scientists have criticised present fisheries management system as ineffective, partly because of emphasis on effort and mesh sizes and largely ignoring environmental and human induced impacts (Cowx, 2005; Kolding

et al., 2008; LVBC, 2011). Other strategies such as management of nutrient loading (COWI, 2002), wise use and management of wetland resources (Gichuki, 2003), sustainable management of fish stocks (Ogutu-Ohwayo & Barlirwa, 2006), control of invasive species introductions (Njiru *et al*., 2005), community participation or co-management (Kundu *et al*., 2010), coordinated regional research and monitoring (Ntiba *et al*., 2001) have all been proposed but little outcome can be reported. In short, simple blueprint policies do not work. We think that most of these ideas have been a part of planning and education for decades and can only be viewed as "old wine in new bottles" considering the current fluidly environmental conditions. Instead, special focus should be invested on limiting access and provision of alternative livelihood for the communities bordering Lake Victoria. Some empirical evidence has suggested that local people are more likely than the central government to manage and conservation natural resources and biodiversity because their livelihoods depend on them (Winter, 1998; Swift, 1991; Cousins, 1996; Jentoft, 2004). They have special social functions for conflict resolution mechanisms and misuse control. In his book titled *governing the commons*, Ostrom (1990) demonstrated how common property systems actually work and how all members of the community access the natural resources with minimal impacts. However, this has not worked effectively for Lake Victoria despite efforts by riparian governments to encourage community participation (LVBC, 2011). Berkes (1989) advised that local people must be given full authority, responsibilities and real power to succeed. This is not the case in Lake Victoria commons. Sound science is necessary for commons governance, but is currently not sufficient. Too many strategies for governance of local commons are designed in capital cities or by donor agencies in ignorance of the state of the science and local conditions.

With stagnating capture fisheries in Lake Victoria (Cowx, 2005), aquaculture provides the only opportunity to increase fish production, limit human access and uplift the livelihood of local communities around Lake Victoria. The Kenyan government has already set the pace by funding an ambitious fish farming program country wide and the impacts are positively cascading to the local fish farmers (Musa *et al*., 2012). Other riparian governments should replicate similar efforts to develop aquaculture by funding and introducing innovative aquaculture technologies.

7. CONCLUSIONS AND WAY FORWARD

Absolute human dependence and vulnerability to the lake's resources for their socio-economic wellbeing has created constant pressures and subsequent environmental impacts on the water, wetland ecosystems, fishes and non-fish organisms in Lake Victoria basin. There are no obvious blanket remedies that can serve as models for managing common property resources particularly in highly diverse and dynamic environments such as Lake Victoria and its environs. However, we need to champion for effective natural resource management at the local level through realistic decentralisation of powers to the local elected government bodies to arbitrate management conflicts. They must be given real authority and power to prosecute offenders of the law (Swift, 1991; Berkes, 1989). We believe that local leaders can only implement the laws such as limiting access if they have absolute power and responsibility. At the same time, provision of alternative livelihoods to the people is beneficial to local biodiversity conservation efforts. Local people need education, finance, planning and management tools suitable to their local situation (Jentoft, 2004). The involvement of these end-users is, in particular, expected to increase their sense of responsibility and ownership, thus facilitating the self-enforcement of the management system and in principle the 'sustainability' and equity of the system (Béné *et al.,* 2009). It is therefore the responsibility of all fisheries stakeholders to work closer with the decentralized governments' agencies in order to ensure a better integration of small-scale fisheries into the process of decentralized development, for the greater benefit of the resource, the local economy, and the fisher folks.

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