The status of research on Lake Victoria fisheries: Historical and current data on fisheries and the lake environment

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Abstract

Lake Victoria which is the second largest freshwater lake in the world supports a large population living around it through provision of food; fish and employment; both directly and indirectly. Due to its varied uses, human intervention within the lake and its catchment has caused several ecological changes in the recent years which have had profound effects on its resources. Historical and recent data within the lake show an enormous change in the diversity of the fish species as well as environmental and ecological changes. Some of the reasons cited for the changes in biodiversity within the lake are: the introduction of alien fish species like Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) into the lake, habitat loss and the cultural eutrophication. Several research projects like Lake Victoria Management programme (LVEMP) and Lake Victoria Fisheries Organization (LVFO) have been formed to help address some of these problems with varied levels of success. There is therefore an urgent need for management measures based on sound scientific research to be taken in order to curb this loss of ichthyodiversity within the lake and to save the livelihoods of the people who are dependent on the lake. Owing to the importance of the lake to the livelihoods of the people around the lake and beyond, there is need for concerted effort by all stakeholders in trying to halt the degradation and other negative environmental and ecological changes within the lake. Ecosystem approach to conservation is the way forward in the management and sustainable utilization of the fisheries and other resources within the lake.

Key words: Lake Victoria, Research, Fisheries, Eutrophication, Extinction

1. Introduction

Lake Victoria is the world's second largest lake with an area of 68,800 km^2, mean depth of 40 m and is shared among three East African countries (Kenya, Uganda and Tanzania). It supports one of the world's largest freshwater fisheries providing employment and food to millions of Africans living around the lake and beyond. The fish yield from the lake is estimated at 1 million tones per year (LVFO 2009). Some of the problems facing the lake are intensive non-selective fishing, catchment degradation, industrial and agricultural pollution, the introduction of exotic species (e.g. Nile perch and Nile tilapia) and uneven patchwork of governmental laws (Ogello *et al*., 2013). The researchers in fact uphold Hardin’s argument that freedom of the commoners has caused resource overuse in the lake leading to poverty and therefore recommend access limitation as a way of encouraging wise use of the lake’s resources.

The lake has attracted much interest in recent years with several research projects and organizations collecting data on several aspects of the lake from its fisheries to ecological aspects. Some of the research projects and organizations associated with the lake include the Lake Victoria Environmental Management Project (LVEMP), Lake Victoria Fisheries Organization (LVFO) among others. These, projects and organizations have had various challenges and successes as discussed in this paper. Fish is known to react to environmental degradation, overfishing, predation, competition and series of environmental changes

(Balirwa et al., 2003). Some of the reactions by fish to these changes have been the decline or even disappearance of some fish species within the lake. This has profound effect on the fishery of the lake and livelihood of the people who depend on the lake. Other problems include the impact of introduced species like the predatory Nile perch as well as over exploitation of the fishery which has led to reduction or/and even disappearance of some fish species within the lake. The severe reduction in fish species diversity has led to modification in the trophic patterns of the Lake Victoria ecosystem, including alterations in floral and faunal composition, and reduced grazing pressure on phytoplankton (Aloo, 2003). This has not only led to changes in the biodiversity within the lake but also to the water quality especially due to the reduction in the number of grazers leading to algal blooms.

This paper therefore focuses on the historical research findings, the current status of the fisheries and the biophysical environment of the lake. It goes ahead to discuss some of the main research projects and organizations associated with the lake; their achievements and challenges and to suggest possible solutions to the challenges facing Lake Victoria.

2. Lake Victoria's biophysical environment

Lake Victoria, as a shared resource, has undergone substantial changes that have threatened its ecosystem and resources therein. These changes are attributed to, global climatic changes and environmental degradation, which is majorly the anthropogenic activities within the catchment area. The current human population stands at 35 million (Kayombo and Jorgensen, 2006), with this kind of human population around the lake basin, its resources must be overexploited.

The high population density, surrounding the lakes' basin, has subsequently increased the land use in conjunction with the need for agricultural land, which which has led to clearing of vegetation leaving the soil bare. The top soil has continued to remain bear and exposed to the wind and rainwater, which washes them downstream to the lake. These top soil and dissolved organic matter have contributed to the reduction in the lakes transparency as was recorded by Graham in 1927 (Sitoki *et al.*, 2010). The transparency has continued to change considerably since 1927. However, a dramatic decrease was recorded in both offshore and inshore waters in 1980s (Sitoki *et al.*, 2010), as result, algal bloom and high concentration of chlorophyll-a was considered to be the main cause of this reduction in transparency.

The conductivity of Lake Victoria has remained in a stable condition for over 50 years, and this has enabled the lake to fall under category-I according to Sitoki (2010), as lakes with conductivity not less than 600-μS cm^{-1}. The conductivity readings remained at 100-μ S cm^{-1} throughout the entire period in most parts of the lake, and 150-μS cm^{-1} within the Nyanza Gulf. These readings might have been expected to rise, but conductivity is a conservative variable, which is controlled majorly by concentration of dissolved cations (Sitoki *et al.*, 2010).

According the study done by LVEMP on pollutant load, the lake basin hosted 87 large towns, with Kenya leading by 51, Uganda and Tanzania having 6 and 30 respectively. In 2001 alone, the same study showed that the pollutant loading that find its way into the lakes water, from urban areas was at 6955 t/y of Biological Oxygen Demand (BOD), and that of Total Nitrogen to be 3028 t/y. These figures only accounted for the pollutants from the urban areas that were close to the lakeshore (Kayombo and Jorgensen, 2006).

The lakes' basin has 68 major industries, of which 16 are in Kenya, 34 in Tanzania and 18 in Uganda. These industries channel their effluents directly or indirectly into the lake. The pollutant load was estimated based on the quality of water used. Table 1 below summaries the contribution of each country in terms of pollutant load into the lake.

Table1: Nutrient loadings into Lake Victoria from riparian countries

Country	Loading to Lake Victoria (t/y)		
	BOD	Total N	Total P
Kenya	860	57	46
Uganda	1, 487	33	88
Tanzania	3, 259	324	208
Total	5, 606	414	342

Data extracted from Kayombo and Jorgensen, 2006.

The increased inflow of nutrients into the lake waters has resulted into water enrichment. This was estimated to be two to three-fold, since the beginning of the century. Phosphorous and nitrogen concentrations have increased throughout the lake, but with nitrogen concentration more on the littoral zone. Consequently, this has caused an increase in a harmful algal biomass in the lake since 1960 (Angweya *et al.*, 1922). Eutrophication, caused by nutrient inflow, has immensely contributed to the state of anoxia in the water column. A condition that has led to fish kills in the lake. In addition to that, it has also spurred the infestation of water hyacinth.

Water hyacinth, a fresh water macrophyte, was first cited in the Ugandan waters in 1988 (Kateregga and Sterner, 2008). Water hyacinth mat, established itself within the lake due to an increase in nutrient inflow (Njiru and Okeyo-Owuor, 2004). The weed blocks the landing sites, a situation that impedes fishers from accessing the market in time hence leading to postharvest losses. The primary productivity of the lake was also affected by this invasive weed, a condition that has led to low photosynthesis for the phytoplankton that are primary producer of the lake (Njiru *et al.*, 2012). In light of the aforementioned problems associated with the biophysical environment of the lake, several research projects and organizations have been set up to collect data and to formulate best conservation and management practices for the lake. Their roles, successes and challenges have been as discussed below.

3. Research organizations and projects associated with Lake Victoria

Several projects mainly funded by international non-governmental organizations have generated data which have been the basis to come up with better management strategies for the fisheries and other resources within the lake. In the year of 1947, the Lake Victoria Fisheries Board, then known as the Lake Victoria Fisheries Service was constituted to conduct research on the fisheries of Lake Victoria. The very early research work to be done involved the identification of the tilapia commercial fisheries in the lake. The research encompassed the identification of the species with their local names all collating in a comprehensive document (Greenwood, P.H. 1966). The flock of haplochromines was also identified and constituted one of the difficult research work done on the lake.

In 1996, the World Bank funded the Lake Victoria Environmental Management Project (LVEMP). The objectives of this programme was to maximize the sustainable benefits to the riparian communities from using resources within the basin to generate food, employment and income. It was also meant ensure supply of safe water and sustain a disease free environment. Other objectives included to conserve biodiversity and genetic resources for the benefit of the riparian communities; to harmonize national and regional management programs in order to reverse environmental degradation to the maximum extent possible; and to promote regional cooperation. This research project was implemented in collaboration with the research institutions of Kenya, Uganda and Tanzania.

In 1997 the three riparian countries with funding from the European Union formed the Lake Victoria Fisheries Research Project (LVFRP) whose main objective was to assist the Lake Victoria Fisheries Organization to develop a framework for the rational management of the lake's fisheries. The specific objectives of the organization included carrying out stock assessments, training fisheries researchers, rehabilitating and constructing research vessels, equipping research institutes and investigating socio-economic issues related to the lake and its fisheries. According to Lake Victoria fisheries organization, LVFO, as of 2016, Lake Victoria was serving 30 million people with 200000 as active fishers in the lake. The annual catch is 800 thousand tonnes valued at 590 million US dollars (Nunan and Onyango, 2017).

Achievements

The research projects and organizations have recorded several achievements. The first fisheries management plan (FMP) for example, which was an initiative of the LVFO was implemented in 2005-2008. The second plan was implemented between 2009-2014 and the third was scheduled for 2016-2020. Two strategic visions have also been created by the secretariat for 1999-2014 and another from 2016-2020. The FMP brought significant changes to the management of Lake Victoria fisheries (Benedict, 2016). LVFO has also harmonized the regulations and policies as well as standards of management, conservation and sustainable exploitation of the Lake Victoria fisheries. The harmonization of policies among the riparian states has seen better coordination and management of fisheries resources within the lake. LVFO has become a repository for scientific knowledge and information on aquaculture and fisheries within the region. The publication of the African Journal of Tropical Hydrobiology and Fisheries is facilitated by LVFO. The annual census and surveys done by LVFO support science based planning and making of decisions concerning fisheries. Community based management structures have been set up on the sustainable use of fisheries resources through the efforts of the organization. Of notable significance is the formation of Beach Management Units (BMUs). This has enhanced community participation in the management of fisheries resources at the lowest level possible with notable success. Despite the numerous research projects, Lake Victoria has continued to undergo several ecological changes due to the effects of cultural eutrophication mainly driven by population increase and industrialization among other reasons. (Sitoki et al., 2010).

4. Historical and current research information and status of fisheries within the lake.

There were few graduates and undergraduates who did little fishery research in Lake Victoria mainly from Europe during the colonial period. These scientists, would conduct their research over few months and then submit their collected data to European schools and organizations. One of the scientists was Edgar Washington who later became the scientific secretary to the East Africa high commission. Washington played a significant part in the research of fisheries and its management in East Africa (Greenwood, 1966).

From 1905 through to 1920, artisanal practices existed among the people of the riparian countries of Lake Victoria in conjunction with gillnet commercial fishery. The commercial fishing mostly was done on the northern shores of Lake Victoria. All through to the 1920s the commercial catch stocks dropped and this raised a concern to overfishing in the lake. It is due to this realization that the east African countries requested a research be done on the fisheries of Lake Victoria (Greenwood, P.H. 1966). In 1927, this arrangement bore fruit when a United Kingdom naturalist called Graham was tasked with the responsibility of conducting the first ever conclusive and official research on the fisheries of Lake Victoria. His commission was to study and provide a solution to the decline of tilapia in the lake. Together with Washington, Graham undertook and completed a circumnavigate research on the lake.

Fishing from different points along the shores and also inshore. It was an experimental fishing expedition. The results showed large number of fish species which being new were identified and described in the British Museum (Greenwood, P.H. 1966).

As a consequence of this research, Graham found that the commercial tilapia belonged to two different species which were *Tilapia variabilis* and *Tilapia esculentus*. Other than this commercial tilapia species there were other fish species in the lake which were described in the Graham report. Graham also found it to be true that overfishing had made the tilapia fish stock dwindle especially along the markets and navigation ways of the lake as well as near marketplaces. He recommended several regulations but the most notable was the prohibition of the use of nets with a mesh size under 5 inches(Greenwood, P.H. 1966).

In the early 1950s, there was a decline in the tilapia fisheries of Lake Victoria. According to Buchman the decline in tilapia species was not due to lack of food or due to predation but mostly due lack of enough and appropriate breeding grounds preferred by these species. The littoral region had become populated with papyrus and other aquatic plants and thus this zone had become unconducive for breeding. This scenario however changed in 1965 when there was a rise in the level of the lake's water. This rise of the level water led to an increase in the abundance of tilapia species due to increased breeding grounds on the littoral shores of the lake (Greenwood, P.H. 1966).

In the year 1953, the Ugandan fisheries sector proposed the introduction of Nile perch into the lake so as to feed on the 'useless' haplochromines in the lake as they termed them. The decision was objected by their counterparts on basis of the effect this would have on the commercial tilapia species. To convert the haplochromines into more useful useable protein was the reasoning behind the suggestion. Nile perch was introduced in the lake amidst opposition and a few years later Nile perch commercial fishery had become the greatest in

Africa (Greenwood, P.H. 1966). The euro annual report (East Africa High Commission 1955) on haplochromines, fishes of Uganda and fish species of Lake Victoria, reported that considerable progress had been made with the taxonomic revision of the haplochromines inhabitants of Lake Victoria. Several papers had been submitted to the bulletin of the British Museum and dealt with *Macroplerodus bicolar* which was believed to occur in the littoral regions feeding on snails and larvae of insects, most commonly the mayfly. The haplochromines were therefore grouped into different groups and that information exists in the bulletin of the British Museum. In 1956 a book was completed detailing all the fishes of Uganda giving an account on the geographical location of the fishes. This journal described all the species belonging to the cyprinids, mormyrids, characids and citharinids (East Africa High Commission 1955).

After the introduction of Nile perch in the 1950s, a research done by (Wanink 1998) showed that *Rastrineobola argentea* had undergone some phenotypic changes. The changes included a 50% reduction in the mature female body size. According to (Wanink, 1998), the changes in the maturity length of *Rastrineobola* spp were prompted by the onset of the Nile perch in the lake. The fishery of the *Rastrineobola* species is a new trend in the current fishery and its re-emergence is attributed to the decline of the Nile perch in the lake. In the Tanzanian side of Lake Victoria, a lot of fisheries is being directed towards these small species. According to (Sharpe, and Chapman, 2012) *Rastrineobola* species fished in the northern part of Lake Victoria are bigger in size than those inshore areas, another finding indicated that smaller *R. argentea* is found in fished grounds than in non-fished waters. The explanation given to the changes in *R. argentea* is; due to increased pressure from predation by the *Lates niloticus* and overfishing, the *R. argentea* went through changes to reduce their sizes that are caught by the mesh sizes and the sizes preferred by the predators. On the other hand, over the decades after the introduction of Nile perch the *R. argentea* have increased in biomass. According to

(Sharpe et al., 2012), the change is brought by a decreased population of cichlids that fed on *R. argentea*. The result is a consequence of competitive release.

In 1979 a research was conducted by Marten, 1979, on the impact of fishing on the inshore fishery of Lake Victoria. According to Marten as a result of increasing human population, the fishing pressure would automatically increase. He cautioned that overfishing should not be looked at the number of fishermen in the lake because at the time Lake Victoria had a low number of fishermen compared to other lakes in Africa, fishing intensity should be the subject of approach. High fishing intensities mean high landings, high yield and production of the fisheries. The report indicated that the biomass of the haplochromine species had reduced due to intensive fishing. To be further accurate, the size of the haplochromines fished had reduced and this can be explained as a survival adaptation. The use of smaller gill nets led to the decline of the preferred tilapia species of the lake and an increase in the large tilapia species that were considered to be trash species. The local community saw this predator as unfit for human consumption and thus termed it to be trash. This was a sign of succession by use of the gill nets that cropped the desired tilapia species.

Small research vessels had been used to research on the changes of the haplochromines from 1979 to 1997. This was conducted on a transect in Mwanza Gulf on the Tanzanian portion of the lake. It is reported that there were high densities of the haplochromines till the 1970s where they reduced rapidly and drastically in 1980s. In 1978, the demersal stock had been dominated by the haplochromines and Nile perch was in very low stocks. In 1987, 97% of the catches of the research vessels were the Nile perch. Through to 1997, the Nile perch catch had reduced to 76% while the haplochromines had increased by 21% (Gichuki et al., 2001).

In early 2000, a research expedition by the LVFO revealed that over five years, the Nile perch catch had reduced significantly. The condition was manifesting itself in varying degrees in different locations. The decline in the Kenya-Uganda border had been gradual while on the Tanzania- Uganda border the drop had been drastic. In the former, the fishing effort had increased significantly but the catch had maintained a plain position. On the latter on maintaining the same fishing effort, the catch had reduced. Mugabo and Sota landing zones recorded a good day's catch of 200kg with a boat having 5 single nets while as early as 2001, fifty nets on a boat would bring 50kg. The fishers adjusted their gears from 5.5-6 inches nets at peak season (January to May) and 7-10-inch nets in the off-peak seasons (June to October). Longlines were common during the off-peak season and would catch 400-800 kilograms a day as the nets would only achieve 20 kilograms a day.

As presented in Table 2 below, the study conducted by LVFO in 2000, on the whole lake to determine the fishing effort of Lake Victoria, showed that the fishing pressure on the lake was very severe. Along a shoreline of 3450 kilometres, 1493 landing sites were identified. This meant that in every 2.3km a landing site existed. A rough estimate of 25 thousand fishermen using 42528 different fishing gears was recorded along the shoreline of the lake. The Nyanza gulf recorded the highest fishing effort with more than 10 fishermen per every square kilometre. There was, therefore, evidence of overexploitation. The decline of the fish stocks only meant tragedy to the livelihoods of about 30 million people (Ochieng, and Mbonge, 2013).

Table 2: Summary of the Lake Victoria fisheries frame survey, March 2000

Item			Country		Total
		Kenya	Tanzania	Uganda	
Landings	No. of landing sites	297	596	597	1490
Fishermen	No. of fishermen	33037	56060	34889	123986
Fishing	No. of fishing	10014	15489	15544	41047

Crafts	Vessels				
Propulsion (Engines)	No. of engines	509	1540	2031	4075
Gears	No. of fishing gears	1096607	2455898	5587980	4140485
Transport Boats	No. of transport boats	409	639	910	1958

Data extracted from (Heck, and Lwenya, 2004)

According to (Ouma, and Ngugi, 2001), *L. niloticus, Cyprinus carpio, Tilapia zillii, Oreochromis niloticus, O. leucostictus* and *O. melanopleura* are the species of fish introduced into Lake Victoria. In their study on the impact of fish introductions on the biodiversity of Lake Victoria, Ouma *et al* identified several impacts on the biodiversity of the lake. These are discussed in the section under the current data and status of some fish species in Lake Victoria.

A research was done by (Njiru, and Muhoozi, 2008), on the changes that have taken place in lake Victoria fisheries as well as the steps taken to revert the changes indicated a decrease in commercial catches of the Nile perch as of 2005. With Nile perch accounting for the 90% of the commercial catches of Lake Victoria. 30000 metric tones of commercial fisheries were recorded in the 1970s, 560000 metric tons in the 1990s and 500000 metric tons as of 2005. The decrease in the fishery production of the lake has been attributed to different ecological as well as social-economic factors. The algal blooms which are most toxic involving mostly the cyanotoxins, the increases macrophytes, increased temperatures and overfishing are some of the reasons the fisheries have deteriorated. Important to note is that the commercial fisheries of the lake have left the locals with little to depend on. As the large commercial Nile perch fishes are caught and taken to large factories for processing, the locals are left with the juvenile Nile perch to fend for themselves and also the skeletons of the Nile perch after processing in the factories (Njiru et al., 2008)

In 2004, a study was conducted on the diel vertical migration of the fishes of Lake Victoria by (Goudswaard et al., 2004), revealed that active hunters such as the Nile perch, zooplanktivorous haplochromines migrated in the surface water column at night. Adults are usually closer to the surface than the juveniles especially the dagaa. Adult fish are found at the bottom during daytime as tapeworm infested juveniles swim closer to the water surface. The migration was attributed to predator-prey relationships and also for mate enticement purposes. This information is useful to the fishers because they understand the best time to fish for certain species of fish at the desired size.

A study done in 2008 on the effect of water hyacinth on the catchability of fish in Kenya, Uganda and Tanzania by (Kateregga and Sterner, 2008), showed that catchability of fish in Lake Victoria had reduced by a factor of 2-45%. The reduced catchability due to the infestation of water hyacinth was recorded in Kenya; which brought trouble to the shipping, hydropower and covering the fishing grounds as well as covering the waterways. This was however seen as a way of reducing the fishing pressure and intensity on the lake(Eggert, and Kidane, 2015).

Among the challenges identified to hindering equity in the distribution of benefits included unequal distribution of assets that involved in the production, these being capital, as well as equipment and skills; the determination of the price is based on a free-market approach, the lack of fisher's organizations to work on their bargaining power, limited investment horizon and opportunities. Poor or inadequate postharvest techniques and majorly the facilities, inappropriate savings avenues and credit accessibility.

Conclusions

The loss of biodiversity of fish in Lake Victoria are mainly due to loss and degradation of habitat, eutrophication, predation and competition from introduced non-native fish species (Nile perch and Nile tilapia) and in some cases, unsustainable use of the lake such as overfishing or use of wrong fishing gears. These if not checked will lead to further decline in numbers of fish species and even extinction.

Recommendations

There is need therefore for further research especially on the biology and ecology of these fish species coupled with concerted efforts to formulate policies to ensure sustainable utilization of the resources of the lake. Future fish introductions into the lake should be based on sound scientific research to avoid the negative consequences witnessed with the previous introductions. Breeding and culture of the endangered species as a means of establishing 'seed banks' for the endangered species is an option that needs expansion, exploration and research. Fingerlings produced in these seed banks can then be re-stocked into the lake to boost the wild population.

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