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A review on the status of some major fish species in Lake Victoria and possible conservation strategies

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Abstract

Lake Victoria, the second largest freshwater lake in the world, supports an enormous flora and fauna biomass, with a large human population around the Lake. The lake is a source of food (fish), water for domestic use and crop and livestock production, transportation and tourism, among other uses. As a result of these varied uses, human intervention within the lake and its catchment has resulted in several ecological changes in the lake in recent years, with profound effects on its fish resources. One of the most notable changes is the reduction and risk of extinction of some fish species, including the endemic tilapiine species (*Oreochromis esculentus* and *Oreochromis variabilis*), catfishes (*Xenoclarias eupogon*), haplochromines and cyprinids (*Labeo victorianus* and *Barbus altinialis*) in the lake. The reduced biodiversity, as well as extinctions within the lake, has been attributed to the introduction of alien fish species (e.g. Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) into the lake, habitat loss and cultural eutrophication. If left unchecked, these changes will have devastating effects on the lake's resources, as well as to people living around the lake and beyond who depend on the lake fisheries for their livelihood. Thus, there is an urgent need for management measures based on sound scientific research to be implemented in order to curb the loss of ichthyodiversity within the lake, as well as to save the livelihoods of those stakeholders who are either directly or indirectly dependent on the lake.

KEYWORDS

diversity loss, endangered, haplochromines, Lake Victoria

1 | INTRODUCTION

Lake Victoria is the world's second largest lake, with an area of 68,800 km^2 and a mean depth of 40 m, being shared between Kenya (6%), Uganda (43%) and Tanzania (51%). It supports one of the world's largest inland freshwater fisheries, providing employment and food to millions around the lake and beyond (Darwall, Smith, Lowe, & Vié, 2005). It exhibits a total annual fish catch of about a million tonnes (LVFO, 2009), with Tanzania contributing 66.6%, Uganda 18.6% and Kenya 14.8% (Turyaheebwa, 2014). The value of the catch at the beach level is estimated to be more than US$ 550 Million, with an export value of US$ 260 Million. The problems facing the lake are intensive, including non-selective fishing, catchment degradation, industrial and agricultural pollution, the introduction of exotic species (Nile perch; Nile tilapia) and an uneven patchwork of governmental laws (Ogello, Obiero, & Munguti, 2013). Ogello et al. (2013) highlighted Hardin's argument that freedom of the commoners has caused resource overuse in the lake, leading to poverty, therefore recommending access limitation as a means of encouraging wise use of the lake's resources.

Lake Victoria has attracted much interest in recent years with several research projects collecting data on several aspects of the lake ranging from its fisheries to ecological aspects. The interest in fish results from the fact that fish react to environmental degradation, overfishing, predation and competition, as well as other environmental changes (Balirwa et al., 2003). Some of the changes have been the decline, or even disappearance, of some fish species within the lake, with significant effects on the lake fishery and associated livelihoods of the people dependent upon the lake. Mainly funded by international non-governmental organizations, several projects have generated data that have been a basis for developing better management strategies for the fisheries and other resources within the lake. As an example, the World Bank funded the Lake Victoria Environmental Management Project (LVEMP) in 1996 with the primary objective being to restore and sustain the ecology of Lake Victoria and its fisheries (Mungai et al, 2019). This research project was implemented in collaboration with research institutions in Kenya, Uganda and Tanzania. Their focus is the generation of new data on the status of the fisheries, as well as other ecologically important information on the portion of the lake within each of the respective countries, and to formulate scientifically sound management strategies. Despite numerous research projects, however, Lake Victoria has undergone several ecological changes attributable to the effects of cultural eutrophication, driven mainly by increased population and industrialization (Sitoki et al., 2010). Other stresses include the impacts of introduced species such as the predatory Nile perch, as well as overexploitation of the fishery, the latter leading reduction and/or even disappearance of some fish species within the lake. A severe reduction in fish species diversity has resulted in modifications to the trophic patterns of the Lake Victoria ecosystem, including alterations in floral and faunal composition, and reduced grazing pressure on phytoplankton (Aloo, 2003). These impacts have not only led to biodiversity changes within the lake, but also to its water quality, the latter attributable mainly to a reduced number of grazers, thereby leading to algal blooms.

There is need to feed an ever-growing population, especially in Africa, including both the appropriate quantity and quality of food. East Africa, for example, is characterized by severe malnutrition (Sunguya, Koola, & Atkinson, 2006). To this end, fish are a cheap and healthy source of protein (Keriko et al., 2003). Lake Victoria previously supported diverse fisheries of cichlids and cyprinid species which, unfortunately, are in decline and even risk extinction because of overexploitation, use of improper fishing gears, introduction of alien fish species (Nile perch), eutrophication (Sitoki et al., 2010), overfishing and water hyacinth (Darwall et al., 2005). Eutrophication and siltation also hinder mate selection and feeding in fishes (Seehausen, Witte, Katunzi, Smits, & Bouton, 1997). About 8% of the native fish species in Lake Victoria are endangered, faced with danger of extinction (Darwall et al., 2005) because of the various anthropogenic activities in the region.

Accordingly, the present study focuses on the status of some major fish species within Lake Victoria, as well as the ecological changes that might have caused a decline in the number of fish species in the lake. It also suggests possible actions that could be taken to reduce the loss of biodiversity, as well as curbing or reducing further ecological changes within the lake.

2 | STATUS OF SPECIFIC FISH SPECIES IN LAKE VICTORIA

Based on the experience of Arksey and O'Malley (2005), a literature search was conducted for various databases including, but not limited to, the Directory of Open Access Journals, Google Scholar, Web of Science and many other databases. As presented below, the materials on the fish species of concern were reviewed, and those containing similar information and facts were clustered together. Based on analysis of articles with differing opinions and facts, logical conclusions were reached and recommendations for enhancing the status of specific Lake Victoria fish species were developed.

2.1 | The cyprinids

Lake Victoria once supported an array of Cyprinid species, some of which are endangered or have disappeared completely, based on catches in the recent years. The severe reduction of *Labeo victorianus* (locally known as 'Ningu'), the only Labeo in Lake Victoria and its catchment, was particularly prominent. A general decline in the catch of *L. victorianus*, a potamodromous fish species, was observed around 1979 (Table 2), coinciding with the replacement of weirs and barriers by beach seins and small mesh size nets set at the river mouths. This is hypothesized to have led to a further decline in the population of this fish in subsequent years (Kibaara, 1981). The contribution of *L. victorianus* to the fish catches in the 1960s was 595 tonnes in 1968 and 467 tonnes in 1969, respectively (Kibaara, 1981). The catch decreased in the late 1980s from 204 fish/ha to <1/ha in the 1990s and later years (Balirwa et al., 2003). Despite this magnitude of its decline, catches were reported for some rivers (Nyando; Mara; Yala; personal observation), although the numbers were considerably reduced, as was the length of the fish at maturity. This situation could be a survival tactic in response to an overfishing pressure, a situation documented for Nile tilapia in Lake Victoria (Njiru, Okeyo-Owuor, Muchiri, & Cowx, 2004).

The decline in the number of *Labeo* in the Kenyan waters of Lake Victoria can be attributed to such fishing practices as the use of fish traps at the river mouths during their migration, resulting in catching mature fish before spawning. This hinders the chances for the gravid fish to contribute to the next generation, leading to a decreased number of fish (Rutaisire & Booth, 2004). *Labeo victorianus* is on IUCN Red List of Threatened species (Maithya, Charo, Wangila, Ouma, & Orinda, 2003), indicating an urgent need for more research on the biology, ecology and potential propagation of this fish in captivity and culture. Such activities will not only reduce pressures on the wild fisheries, but also help boost their population in the wild through the re-introduction of the hatchery-bred fingerlings into the lake and the rivers flowing into it. Attempts to breed *Labeo* in captivity in Kenya (Maithya et al., 2003) and Uganda (Rutaisire & Booth, 2004) have been tried with significant success, enhancing the possibility of saving this endangered species.

Barbus altinialis is another cyprinid whose numbers have decreased considerably in the catches around the lake. The species is also listed in the IUCN Red List of Threatened Species. Though still caught in some rivers (Migori; Mara; personal observation), they are rarely seen in other rivers and commercial landings (personal communication by fishermen). The contribution of this fish to the fish landings around the lake has declined from 8,173 tons in the 1980s to 152 tons in the late 1990s and early 2000 (Balirwa et al., 2003). There could have been a further decrease in the numbers, since the fish has seldom been observed in current catches. Recent studies in the basin reported the presence of this species in the mid- and lower reaches of Kenyan rivers flowing into the lake (Mwangi, Ombogo, Amadi, Baker, & Mugalu, 2012).

2.2 | Haplochromine cichlids

The upsurge of the introduced Nile perch, compounded with reduced water quality attributable especially to eutrophication, has negatively impacted the number of haplochromine species in Lake Victoria (Darwall et al., 2005). Most Haplochromine species have decreased significantly in number except for a few species such as *Haplochromis pyrrhocephalus*, which have undergone some morphological changes to overcome pressures from Nile perch (Witte et al., 2008). Katunzi, Zoutendijk, Goldschmidt, Wanink, and Witte (2003) observed that *H. pyrrhocephalus* changed feeding behaviour from predominantly fish to include shrimps and molluscs as a tactic to reduce niche overlap with Nile perch. Although most haplochromine cichlids of Lake Victoria are known for exhibiting rapid evolution, with an estimation of over 500 endemic species having evolved over the last 100,000–400,000 years, eutrophication pushed most of them to near extinction (Awiti, 2011). It is estimated that out of over 500 haplochromine species within the lake before the introduction of Nile perch, nearly 200 are now extinct (Goudswaard, Witte, & Katunzi, 2008). Simo, Freire, and Simberloff (2009) observed that resource competition could be the most probable mechanism for the impacts of the introduced species, other than predation. Nile perch were observed to fed mainly on haplochromine cichlids, and it is reported this led to a rapid decline in the number of haplochromines in the lake (Kitchell, Schindler, Ogutu-Ohwayo, & Reinthal, 1997). In the 1970s, for example, the contribution of haplochromines to the Lake Victoria fish catches was 22,464 tonnes (28.8%) and 32,552 tonnes (40.6%) in 1975 and 1976, respectively (Witte & Oijen, 1990). This contribution decreased sharply to 128 tonnes in 1980s, and further to four tonnes in the 1990s and 3 tonnes in 2000 (Balirwa et al., 2003; Goudswaard & Witte, 1997).

Most haplochromines are trophic specialists with a strict choice of diet, maturing at a small size and low productive potential due to their small clutch sizes. They also have extended parental care, making them vulnerable to most environmental and ecological changes, especially predation (Goudswaard et al., 2008). Haplochromines are known to spend more time and energy protecting their young ones, which sometimes leads to their capture by predators. The rate and sequence of haplochromine decline within the lake were determined by their relative abundance and their adult size, as well as their habitat overlap with Nile perch (Witte et al., 1992). As Nile perch are both better competitors and a predator of the haplochromines, the habitat overlap is disadvantageous to haplochromines since it increases their interactions with each other (Outa, Mungai, & Keyombe, 2019). The rate of disappearance differed among the different feeding guilds. The relatively large piscivores, insectivores and molluscivores were the first to disappear from the catches. The small detritivores and zooplanktivores declined at lower rates (Seehausen et al., 1997; Witte et al., 2007). This could be largely attributable to the size, noting larger fish are easier to spot and pursue by the predatory Nile perch. The exotic Nile tilapia is also suspected of having negative impacts on haplochromine cichlid biodiversity through hybridization, overcrowding, competition for food and the introduction of parasites and diseases from their native environments (Awiti, 2011). Some satellite lakes (e.g., Lake Kanyaboli; Yala Swamp) have been hypothesized to be refugia of haplochromine species.

2.3 | The African catfishes

Catfishes in Lake Victoria have been declining, with the numbers of these indigenous fish having decreased drastically since the beginning of the 1980s (Dadzie & Ochieng-Okach, 1989; Goudswaard & Witte, 1997). The overall catfish stock in Lake Victoria is estimated to be 90 tonnes, with the standing stock of *Bagrus docmak* estimated to be 2,788, 22,131 and 14,766 tonnes in the 1970s in the Kenyan, Tanzanian and Ugandan portions of Lake Victoria, respectively. Yearly catches fluctuated between 500 and 17,000 tonnes, but decreased to <200 in 1988. About 1,000–1,800 tonnes were landed annually in the Kenyan waters of Lake Victoria until 1983, followed by a decline (Goudswaard & Witte, 1997; Kudhongania & Cordone, 1974), being attributed to the introduction of Nile perch and the ecological changes taken place within the lake over the years, including deoxygenation of the deeper waters and a decline in the haplochromine cichlids that constituted an important food source for this fish. As an example, the 1980s *B. docmak* was known to feed predominantly on haplochromines. However, the diet changed to *Ratrineobola argentea* and oligochaetes in the recent years, most likely because of the decline in the number of haplochromines in the lake. Before the establishment of the predatory Nile perch, the 1980s *B. docmak*, *Clarias gariepinus* and *Schilbe intermedius* were the top predators within the lake (Goudswaard & Witte, 1997).

The *Xenoclarias eupogon* biomass was estimated to be 447 tonnes in Lake Victoria in the early 1970s. The catch rates have declined over the years from 18, 0.6 and 0.3 (number of fish caught) per hectare in 1984, 1985 and 1986, respectively (Goudswaard & Witte, 1997), and the fish is currently thought to have gone extinct. *Synodontis victoriea* and *Synodontis afrofischeri* are still present in small numbers in shallow areas of the lake (Bwanika, Chapman, Kizito, & Balirwa, 2006), being considered mostly as bycatches in the fishery of *R. argentea*, the latter being a dominant cyprinid within the lake. *Schilbe intermedius* and *C. gariepinus* are the least affected of the catfishes in the lake, possibly attributable to a smaller habitat overlap with Nile perch than the other catfish species. *Schilbe intermedius* is partly pelagic, while *C. gariepinus* live in water bodies surrounding the lake and, therefore, can return to the lake through river inflows, thereby boosting their numbers within the lake (Goudswaard & Witte, 1997). *Schilbe intermedius* was estimated to comprise 646 tonnes in the 1969–1970 period (Table 1), with the number continuing to decline over the years. The catches of these fish are occasionally included in the catch data, as they were considered to be of low commercial value, making their estimation rather difficult. The other threat facing most African catfish species, especially *S. intermedius* and *S. victoriea*, is the gill net fishing in the river mouths, especially during the rainy seasons. This practice leads to the elimination of the gravid male and female fish migrating upstream to spawn. Goudswaard & Witte, (1997) argue, however, that there is no indication overfishing has led to the decline in catfishes in Lake Victoria, especially in the deeper waters.

2.4 | The African lungfish (*Protopterus aethiopicus*)

The African lungfish (*Protopterus aethiopicus*; 'Kamongo' in Luo) is a special kind of fish, especially among the communities living around the lake. With its snake-like appearance and strong taste, coupled with the lower bone-to-flesh ratio, it occupies a particular category for fishermen and consumers. The decrease in the number of African lungfishes could be a result of the conversion of most wetlands, which served as their refugia to agricultural fields. Harvesting of nest-guarding male lungfish also could have contributed to the decreased recruitment of the young ones, leading to a decline in their numbers in Lake Victoria (Goudswaard, Witte, & Katunzi, 2002). Other possible reasons for their decline could be the impacts of the Nile perch, declining food abundance and habitat degradation. Goudswaard, Witte, and Katunzi (2002) reported a decline in the catch of lungfish from 67.5 to 5.5 kg/ha between 1973 and 1986, while the catches decreased from 0.3 to 0.07 tonnes (Table 1) between 1986 and 1990. Little research has been conducted on the culture and propagation of lungfish in captivity, indicating a need to protect and manage their dwindling populations within Lake Victoria.

2.5 | The tilapiines

Some indigenous tilapiines to Lake Victoria and its affluent rivers (e.g., *Oreochromis variabilis*) have also come under serious threat (Maithya et al., 2003). This species, together with the native *Oreochromis esculentus*, was a lucrative fishery within the lake in the early 1960s, but has significantly declined over the decades because of various changes within the lake, such as predation from the introduced Nile perch, as well other environmental and ecological changes over the years (Goudswaard, Witte, & Katunzi, 2002). The number of tilapiines decreased in the 1970s and increased in the late 1990s and around 2000 (Table 1 and 2). This could be attributable to the introduced Nile tilapia, which also resulted in a decreased *O. variabilis* and *O. esculentus* populations, and an increase in the landings of the tilapiines in general. The contribution of *O. variabilis* decreased from 26 fish/ha in the early 1970s to less <1 fish/ha in the late 1980s and subsequent years. Although data on these two species are sparse, fish landings around the lake exhibited a decline in their numbers.

According to Sitoki, Kurmayer, and Rott (2012), eutrophication has resulted in increased blue-green algae biomass that has replaced the diatoms, which are the preferred diet of *O. variabilis* (Maithya, Njiru, Okeyo-Owuor, & Gichuki, 2012). Nile tilapia (*Oreochromis niloticus*) was introduced into the lake in the 1950s to enhance the declining tilapiine fishery, and as with the Nile perch, the ecological effects of this introduction were taken into consideration (Njiru et al., 2004). Being a superior competitor, *O. niloticus* has gradually replaced *O. variabilis* and *O. esculentus* (Aloo, 2003; Awiti, 2011; Njiru, Waithaka, Muchiri, Knaap, & Cowx, 2005). The introduction of *O. niloticus* and *Tilapia zillii* has resulted in the replacement of the endemic species (*O. esculentus* and *O. variabilis*) with possible hybridization as speculated by Lowe-Mc Connell (2009). It was observed that the contribution of these two fish species begins declining gradually to a point of disappearance in the catches within the lake since establishment of the two introduced species (Lowe-Mc Connell, 2009). Other reasons cited for the decline in the numbers of *O. esculentus* in the lake (apart from competition from Nile tilapia) are replacement of *Aulacoseira* by the less nutritious blue-green algae (Sitoki et al., 2012). The replacement is attributed to eutrophication, since blue-green algae can tolerate high nutrient conditions, in contrast to the former, which is sensitive to nutrient enrichment.

3 | ECONOMIC LOSSES AND POSSIBLE CONSERVATION STRATEGIES

The Lake Victoria fishery provides employment to over one million people and provides over 500,000 tonnes of fish per annum (Njiru, Kazungu, Ngugi, Gichuki, & Muhoozi, 2008). The main contributor to this production is Nile perch and Nile tilapia, although the previously noted indigenous fish species contribute to some extent to the yield. The economic potential of the indigenous fish species of Lake Victoria is enormous. Although not explicitly recorded, these

TABLE 1 Contribution of different species (number of fish caught/ha) in Lake Victoria over time (adopted from Balirwa et al., 2003; Goudswaard, Witte, & Chapman, 2002; Goudswaard, Witte, & Katunzi, 2002; and Goudswaard & Witte, 1997)

	1973	1984	1985	1986	1987	1988	1989	1990	2000
Bagrus docmak	–	23	37	12	2	1	0	0	–
Synodontis afrofisheri	–	10	33	6	6	5	1	1	–
L. victorianus	–	67	163	80	0	0	0	0	–
Schilbe intermedius	–	46	89	72	54	26	12	62	–
Lungfish	67.5	–	–	5.5	–	–	–	0.07	–
Oreochromis variablis	26	15	2	2	0	0	–	0	–
Oreochromis esculentus	–	–	–	–	–	–	–	–	–
Haplochromines	From 1955 to 128		–	–	–	–	–	3	4
Labeo victorianus	From 204 to 20		–	–	–	–	–	0	0

TABLE 2 Contribution (tonnes) of various fish species in Lake Victoria fish catches (Adapted from Balirwa et al., 2003)

Taxa	1966–1967	1976–1977	1986–1987	2000
Tilapiines	17,747	2,480	5,772	30,530
Bagrus	6,646	4,645	8,173	152
Protopterus	2,627	2,035	309	469
Barbus	813	330	85	0
Synodontis spp	122	305	28	127
Haplochromines	1,955	1,280	3	4
Labeo	204	20	0	0

fish species are still the favourite of many people living around the lake region, with *Labeo*, lungfish and catfishes being highly regarded. *Synodontis* spp. are currently used as ornamental fish which, when caught live, command a high price. The loss of these species will clearly result in huge losses in terms of both income and food.

The aquaculture potential of these fish species, particularly *O. esculentus*, *O. variabilis* and *L. victorianus*, has been explored by several researchers over the past few years. In Kenya for example, research has been conducted on determining the best culture systems and practices, as well as the viability of breeding and propagation of *Labeo* in captivity (Abwao, Boera, Safina, Munguti, & Ogello, 2014; Kembenya, Marcial, Outa, Sakakura, & Hagiwara, 2016; Orina, Munguti, Opiyo & Karisa, 2014). Several studies on this species have indicated they can be cultured in ponds with growth rates as good as that for tilapia (Mokoro et al., 2014; Oyoo-okoth et al., 2011). Further, hatchery-produced *L. victorianus* larvae can be transported to culture centres for more than eight hours with insignificant mortalities (Outa & Ogello, 2019), indicating fingerlings are resistant to handling stress, which is vital for restocking programmes. *Labeo victorianus* has been reared under various conditions in Benin with survival rates of up to 98%, and specific growth rates of 15.5%/day (Montchowui, Lalèyè, N'tcha, Philippart, & Poncin, 2012), indicating *Labeo* can be propagated in captivity and enhancement of the wild stock is possible.

The culture potential of *O. esculentus and O. variabilis* has been carried out by some farmers with the aid of researchers in Kenya, with Maithya (2010) reporting up to over a 50% survival rate and mean weight of over 60 g after five months of rearing in ponds. The relatively good growth performance of *O. esculentus* and *O. variabilis* in different ecological zones within the Lake Victoria basin indicates the viability of the species for culture, which can then be used for propagation of fingerlings and subsequent restocking into the lake to boost the dwindling populations. As the growth of most of these indigenous species is very slow, therefore, fish farmers must be cautious before engaging in economic ventures with these species. As pointed out by Maithya (2010), several issues require strict consideration in utilizing endangered species, even if the objective is to conserve them, including the need to maximize effective population size when carrying out hatchery operations, as well as ensuring the populations in the original refuge are left to thrive. Maithya et al. (2003), however, observed that as long as *O. niloticus* dominates in Lake Victoria, and water quality changes continue unabated, the Nile perch will continue to thrive in the lake, with continuing habitat degradation. Thus, restocking into the lake is not a viable means of conservation. Hybridization, particularly between *O. niloticus* and other tilapiine species, is another challenge to be faced. Nevertheless, these interventions should assume these species can be conserved and used as a useful resource.

Other possible conservation measures could be protection of the refugia, especially within the Yala Swamp and the satellite lakes (Kanyaboli; Sare; Kambonyo), all identified as *O. variabilis* and *O. esculentus* refugia (Aloo, 2003). Aloo (2003) found no hybridization in these satellite lakes, suggesting the strains of these two species are still pure. Thus, these areas could be used as sources of pure strains and brood stocks for propagation. Whatever conservation measures are put in place, however, the most important step to be taken is regulation of the fishing pressures within the lake through formulation and enforcement of laws and regulations by the concerned institutions. These regulations should be harmonized for the three riparian countries (Kenya, Uganda and Tanzania), since lack of harmonization of regulations regarding resource management has been a major problem in managing the fisheries resources within the lake (Njiru et al., 2008). Probably, the most problematic issue is the regulations regarding gear selection and usage within the lake, since each country applies its own rules and regulations which conflict with those of the other countries sharing the lake at various times.

4 | CONCLUSIONS AND RECOMMENDATIONS

The loss of biodiversity of fish in Lake Victoria is due mainly to habitat degradation and loss, eutrophication, predation and competition from introduced non-native fish species (Nile perch and Nile tilapia) and, in some cases, the unsustainable use of the lake from overfishing or the use of improper fishing gears. If not appropriately checked and managed, these factors will doubtless lead to a further decline in the numbers of fish species and ultimately even their extinction. Thus, there is a need for further research, especially on the biology and ecology of these fish species, as well as efforts to ensure concerted efforts in formulating policies to ensure sustainable utilization of the resources of the lake. Breeding and culture of the endangered species as a means of establishing 'seed banks' for the endangered species is an option for further expansion, exploration and research. Fingerlings produced as a result of these seed banks can then be restocked into the lake to boost the wild populations.

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