The impacts of introduced species on lake ecosystems: A case of Lakes Victoria and Naivasha, Kenya.

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Abstract

Fish and other aquatic organisms have been introduced into new environments for various reasons. Provision of sports fishery, supplemental to stocks, to fill empty niches, control weeds, and disease vectors and even create a commercial fishery are some of the reasons why fish species are introduced into new ecosystems. Lake Victoria and Lake Naivasha in Kenya have seen several introductions as discussed in this paper. In Lake Victoria for example, some of the species introduced include Nile perch, *Lates niloticus*, Nile tilapia, *Oreochromis niloticus, Tilapia zilii, and Oreochromis esclentus* among others. The most successful introductions have been that of the Nile perch, Nile tilapia and water hyacinth. Lake Naivasha too has witnessed a number of introductions into its fisheries too. Some of the successful introductions into the lake are those of the Common carp, *Cyprinus carpio*, the largemouth bass, *Micropterus salmoides*, the Nile tilapia, *O. niloticus and* Louisiana red swamp crayfish, *Procambarus clarkia.* Aside from the fish species mentioned, some invasive plant species have also been introduced into these two lake ecosystems. Of notable success and impacts have been the water hyacinth, *Eichhornia crassipes* and Nile cabbage, *Pistia stratiotes.* These introductions have had both negative and positive impacts on the fisheries and the ecology of the two lakes. Some of the impacts have been predation on the native species by the introduced species like in the case of Nile perch and largemouth bass in Lake Victoria and Naivasha respectively. Competition for resources and hybridization with the native species has also been witnessed in the case of the tilapiines in the two lakes with undesirable results. Blockage of navigation routes caused by the invasive plants has been a major problem in the two lakes sometimes leading to massive postharvest losses by the fishermen. On the other hand, some introduced species have led to an increase in fish landings as well as utilization of the niches that were initially vacant within these ecosystems. It can therefore be concluded that introduced species often have more negative effects on the native species and therefore such introductions should be based on sound scientific research in order to minimize their effects within the new environments.

Key words: Introduced species, Impact, Lake Victoria, Lake Naivasha

Introduction

The world over, fishery managers have termed fish introductions and fish transfers as fishery management techniques. When a species is introduced accidentally or intentionally into a new water body it is termed as introduced (Mboya, Manyala, & Ngugi, 2005). It can, however, bring in the concept of boundaries whereby if a species is transferred from one region to another may be considered a special case with a species that has been introduced in an ecosystem in the same region. Globally, 237 species have been introduced in 140 countries in a total of 1354 introductions (Mboya et al., 2005). According to (Mboya et al., 2005), around 50 species fish species with 23 species being from out of Africa have been introduced in Africa in a total of 147 introductions. With a total of 14 introductions, Lake Victoria holds a record of 6 introductions, Lake Naivasha with 7 (only one of the present fishes of Lake Naivasha is endemic, the rest are introduced) and one introduction in Lake Baringo. There are varying reasons for the introductions but most of them are seen through the lenses of fisheries management. Provision of sports fishery, supplemental to stocks, to fill empty niches, control weeds, and disease vectors and even create a commercial fishery are some of the reasons why fish species are introduced into new ecosystems. Some of the problems facing the two lakes are intensive non-selective fishing, catchment degradation, industrial and agricultural pollution, the introduction of exotic species and uneven patchwork of governmental laws (reviewed by Ogello *et al*., 2013). Ogello *et al* (2013) in fact uphold Hardin's argument that freedom of the commoners has caused resource overuse in Lake Victoria leading to poverty and therefore recommend access limitation as a way of encouraging wise use of the lakes' resources.

The main objective of this review paper is to elaborate the reasons and of impacts of introducing species in ecosystems with special emphasis on Lake Victoria and Lake Naivasha in Kenya, East Africa.

Introductions in Lake Victoria

Lake Victoria has a surface area of approximately 68000km^2 and a catchment area of 25000km^2. The catchment areas fall under 7 East African countries and this is a very important freshwater resource. The lake has a shoreline of 3200km which is shared among three East African countries in varying proportions where Kenya gets the lowest share of 6%. Tanzania with the greatest share of 54% followed by Uganda with about 40%. About a million tons are harvested from Lake Victoria fishery annually (Njiru et al., 2014). The commercial fishery consists of three species. These species are Nile perch, *Lates niloticus*, Nile tilapia, *Oreochromis niloticus*, and dagaa, Omena, *Rastrineobola argentea*. It is important to note that Nile perch and Nile tilapia are non-native species of Lake Victoria.

Lake Victoria was initially a multi-species, multi-genera fishery which has been reduced to three species fisheries. This is due to the introduction of exotic species which presents economic benefits while exhibiting an ecological disaster. Four species of tilapia, *O. leucosticus*, *O. variabilis among others*, lungfish, about 500+ species of haplochromines initially dominated the lake's fishery. According to (Ogutu-Ohwayo Richard 1990), complete loss and decline of native species have been witnessed in lakes Victoria and Lake Kyoga. Although all the burden cannot be put upon the introduced species, they have a part in the disappearance of a number of the endemic species. *Labeo victorianus* had declined even before the introduction of the tilapia species and the voracious Nile perch. Overfishing and changes in the attributes of the lake can be attributed to the decline of these species according to Ogutu-Ohwayo Richard (1990). Other factors include pollution that has led to eutrophication as well as destruction of wetlands around the lake. About six fish species are reported to have been introduced into the lake with varied levels of success and impacts. Examples include, the Nile perch (*L. niloticus*), Nile tilapia (*O. niloticus*) and other tilapiines. Of noticeable impact on the lakes biodiversity are the two aforementioned. (Ogutu-Ohwayo 2014), terms the introduction of the four tilapia species and the voracious perch as a significant event in the fishery of Lake Victoria.

The Nile perch, *Lates niloticus*

Nile perch was introduced into Lake Victoria in the late 1950s to convert the bonny haplochromines into more commercially viable flesh. Nile perch has been blamed for the extinction of several species of haplochromines within the lake due to its predation pressure on them (Goudswaard et al., 2008; Kitchell et al., 1997; Mkumbo and Ligtvoet, 1992). This top predator exerted too much pressure on the haplochromines especially in the 1980s when its population bloomed in the lake. Most Haplochromine species reduced remarkably in number except for a few species like *Haplochromis pyrrhocephalus* that have undergone some morphological changes to overcome the pressure from Nile perch (Witte et al., 2008). (Katunzi *et al*., (2003) observed that *H. pyrrhocephalus* changed their feeding behaviour from predominantly fish to include shrimps and molluscs which they proposed is a tactic to reduce niche overlap with Nile perch (Katunzi et al., 2003). Although most haplochromine cichlids of

Lake Victoria are known for their rapid evolution with an estimation of over 500 endemic species having evolved over 100,000-400,000 years (Awiti, 2011). It is estimated that out of the over 500 haplochromine species within the lake before the introduction of Nile perch, nearly 200 are now extinct (Goudswaard *et al*., 2008). Nile perch was observed to fed mainly on haplochromine cichlids and it is reported that this certainly led to rapid decline in the number of haplochromines in the lake *(*Kitchell *et al*.,1997). In the 1970s for example, the contribution of haplochromines (in metric tonnes) to the catches of lake Victoria were 22,464 (28.8%) and 32,552 (40.6%) in 1975 and 1976, respectively (Witte and Oijen, 1990). The contribution decreased sharply to 128 tons in 1980s and further to 4 tons in 1990s and 3 tons in 2000 (Balirwa *et al*., 2003; Goudswaard and Witte, 1997). The perch has not only affected the population of the haplochromines but that of other fish species within the lake. Some of the other species impacted upon by the Nile perch are the catfishes (*Clarias gariepinus*, *Synodontis* spp and *Schilbe altinialis*) and to some extent the African Lungfish (*Protopterus aethiopicus*) (Goudswaard and Witte, 1997; Goudswaard et al., 2002). The introduction of Nile perch into the lake was observed to affect even the diet of the Pied Kingfisher (*Ceryle rudis*). This was through reduction of haplochromines which was the most important food source for the bird (Wanink et al., 1994).

The tilapiines

Oreochromis variabilis and *O. esculentus* were the major commercial fishery of Lake Victoria in the early 1920s. Due to overfishing, these species declined in biomass and therefore the fishermen reduced the sizes of their nets to catch the smaller fishes. These included the haplochromines and the silver cyprinid *Rastrineobola argentea*. Haplochromines were trolled and according to (Ogutu-Ohwayo Richard 2014), in 1967, 650000 tons of fish were harvested, 80% of the catch being the haplochromines. The tilapias species introduced were meant to augment the depleted tilapia stocks and *Tilapia zilli* was meant to feed on the macrophytes that were unutilized by the fishes of the lake. The effect of this introduction was realized a decade and a half later when the fishery of Lake Victoria increased fivefold. The Nile tilapia has been blamed for the reduction in the numbers of the indigenous tilapiine species (*O. esculentus* and *O. variabilis*). This is due to its better competitive ability over the indigenous species (Njiru et al., 2006; Njiru et al., 2006b). However, with the increased fishing pressure on Nile perch coupled with the use of wrong gears, researchers have recorded a recovery in some of the Cichlids within the lake (Katunzi et al., 2003; Witte et al., 2007).

In the vicinity of the lake, people depend on fish as their cheapest source of animal protein (Ouma et al., 1993). For instance, tilapiines that were introduced into Lake Victoria have so far resulted in tremendous increases in the quantities of fish landed. This has resulted in enormous consumption since fish is cheaper and readily available (Reynolds et al., 1995; Ogutu-Ohwayo & Hecky, 1991; Ouma et al., 1993). Lake Victoria has a considerable volume of sun-dried, smoked and salted fish products which move to remote markets within the three riparian states and as exports to Sudan, Congo, Rwanda and Burundi (Ouma et al., 1993). Landing-site activities such as portage, net making and mending, canoe construction and repair, and fish processing and marketing have intensified along the lake. This is a replica of what has happened in other tropical lakes in the region including Lake Tanganyika and Kyoga.

Water hyacinth (*Eichhornia crassipes*)

Water hyacinth (*Eichhornia crassipes*) and Nile cabbage (*Pistia stratiotes*), freshwater floating macrophytes, have also established themselves within the lake due to an increase in nutrient inflow (Njiru and Okeyo-Owuor, 2004). Water hyacinth for example blocks the landing sites, a situation that impedes fishers from accessing the market in time hence leading to post-harvest losses. The primary productivity of the lake is also affected by this invasive weed, a condition that has led to low photosynthesis for the phytoplankton that is a primary producer of the lake. This is mainly through shading of the phytoplankton by the mats of the weed. The hyacinth also curtails the interaction at the water-air interface affecting dissolved oxygen within the water column. The weed also affects the distribution of fish thus leading to differences in diversities among habitats within the lake (Yongo et al., 2017). Several attempts have been made by the three riparian countries to control the weed using both biological and mechanical methods with very little success. The surest way of controlling the invasive weed is reducing nutrient inflow into the lake since high nutrient loads has been the reason behind the blossoming of the weed within the lake.

Introductions in Lake Naivasha

Lake Naivasha is a small shallow (3-6 m) freshwater lake situated on the Eastern side of Rift Valley in Kenya. It covers an area of 150 km^2, lies at an altitude of 1890 m above sea level and is fed by two perennial rivers Malewa and Gilgil. It has been recognized as a wetland of both national and international repute. Nationally, it supports a booming floricultural and horticultural farming earning the country considerable foreign exchange, supplies water to Olkaria geothermal power plant which supplies 109 (Otiang'a-Owiti & Oswe, 2007) Megawatt of electricity to the national grid annually, is a source of water for domestic use by the surrounding population, and a source of livelihood to tens of thousands of people working in flower farms and the artisanal fishery. It also has considerable recreational and tourism value. Internationally is recognized for its rich plant (Gaudet, 1977) and aquatic bird biodiversity hosting about 200 species including rare bird species (Abiya, 1996).

Lake Naivasha is a very unstable ecosystem characterized by huge lake level fluctuations of up to 12 m in the last 100 years (Mavuti & Harper, 2005), numerous alien species introductions, increasing anthropogenic activities such as farming, cattle herding, and climatic changes. Starting from 1929 to 2010, a total of 23 alien species had been introduced into lake (Gherardi et al., 2011). The introductions can be put into four categories: (1) intentional fish introductions to enhance the fisheries (1960); (2) accidental arrivals of invasive floating plants: *Pistia stratiotes* (1960s), *Salvinia molesta* (1962) and *Eichhornia crassipes* (1988); (3) the introduction of *Procambarus clarkii* (1970) and the release of weevils for *E. crassipes* biocontrol (1996–2000) and (4) the accidental arrival of carp *Cyprinus carpio* in 1999 (Gherardi et al., 2011).

The Largemouth bass, *Micropterus salmoides*

Largemouth bass, *Micropterus salmoides,* was first deliberate fish species introduced into Lake Naivasha in 1929, and reintroduced in 1940s and 1951 (Gherardi et al., 2011) to enhance the fishery. It is a macro-predator which has had some notable impact on the community structure of the lake. It is believed to have driven the only indigenous fish species of the lake, *Aplocheilichthys antinorii*, a small tooth carp to extinction through predation by 1962 (Harper, et al., 2011). In the past decades, it aided the regeneration of macrophyte beds in the lake by causing the population of *Procambarus clarkii* to crash due to predation (Hickley et al., 2004). The largemouth bass together with the two tilapia species *O. leucostictus* and *Tilapia zilli* formed the basis of an artisanal commercial fishery in the lake before the accidental introduction of Common carp in 1999, thus providing a means of livelihood for small-scale fishers and supplying fish to the surrounding population. From 1987-2000 the mean annual species composition of the finfish catch was *O. leucostictus* 71.7%, *T. zillii* 8.8% and *M. salmoides* 19.5% (Hickley et al., 2004).

The Tilapiines

Various tilapiines have been introduced into to Lake Naivasha since 1925 (Hickley et al., 2002). *T. zillii* (Gervais) and *O. leucostictus* (Trewavas) were introduced in 1956 which led to a commercial gillnet fishery being developed (Siddiqui 1977; Muchiri et al. 1994; Hickley and Harper 2002;Harper, Oyugi, Ntiba, Kisia, & Britton, 2011). However, not all introduced Tilapiines species have thrived in the lake. Populations of *O. spilurus niger* for example are no longer present within the lake. Reasons for their failure have not been tested but were likely to include competition with established species, predation by *M. salmoides* and habitat changes (Siddiqui, 1977; Seegers et al., 2003;Gherardi et al., 2011). The primary drive for introducing these species was to increase catches in the captive fisheries (Nuñez and Pauchard, 2010; Gherardi et al., 2011). While *T. zillii* was introduced to enhance the fishery (Harper et al., 1990; Hickley et al., 2002), *O. leucostictus*, which influenced catches prior to *C. carpio* entry, was brought in as a contaminant of a batch of *O. niloticus* (Gherardi et al., 2011). Nile tilapia, *O niloticus* was introduced into the lake in 2011 under the Economic Stimulus Program (ESP) by the Kenyan government. The main reason for the introduction was to boost the tipaiine catches which was dominated by *O. leucstictus* which does not grow to big sizes. The fish has since established itself very well within the lake (Outa et al., 2014). The reason for its establishment is similar to those cited for its establishment in Lake Victoria; high fecundity, highly flexible feeding habits. These among other characteristics make it a better competitor. Mixing of tilapiine spp. as a result of introductions appear to have resulted in elimination of some species through competition. Not all of the four alien Tilapiine species have thrived in the lake. Populations of the introduced *O. spilurus niger* for example has since disappeared from the lake. Reasons for its failure have not been tested but were likely to include competition with established species, predation by *M. salmoides* and habitat modification (Siddiqui, 1977; Seegers et al., 2003;Gherardi et al., 2011). Hybridization between *O. leucostictus* and *O. spirulus* was followed by the disappearance, first of *O. spirulus* then the hybrids from this lake Lake Naivasha (Ouma et al., 1993). In Lake Naivasha the tilapias, *O. leucostictus* and *T. zillii*, with their large uptake of detritus, represent mud-feeders. *O. leucostictus* also partly fulfils the role of microherbivore by taking green algae and diatoms, although this species alone is unlikely to fully exploit phytoplankton production. Of the larger plant material, some is eaten by *T. zillii* (Hickley et al., 2002).

Louisiana red swamp crayfish, *Procambarus clarkii*

In about 1970, 300 *Procambarus clarkii* from Subukia Dam were introduced into the east side of Lake Naivasha deliberately to enhance the fishery (Harper & Mavuti, 2004). It flourished and established itself in the lake within a period three years. It has had huge impact on the ecology of Lake Naivasha. It is credited with drastic changes to the composition of the community of the lake. Being a vociferous omnivore, it caused drastic reduction and loss of submerged and floating macrophytes in the lake through consumptive and non-consumptive destruction (Adams et al., 2002). The blue water lily *Nymphaea nouchalii* and other floating-leaved and submerged macrophytes declined in coincidence with crayfish population expansion in 1974–1980 with evidence of direct consumption (Harper & Mavuti, 2004). It is an important diet component of *Macropterus salmoides* and *C. carpio*, piscivorous aquatic birds (e.g. cormorants and herons) and mammals (e.g. otters) (Smart et al. 2002). Due to its bottom burrowing tendencies it causes bioturbation thereby reducing lake transparency and adversely affecting visual feeders such as *M. salmoides* leading to declines in catches (Britton et al., 2010).

It is also linked to reduction of Mollusca, Hirudinea, Trichoptera and Ephemeroptera (Clark et al., 1989) by adversely impacting their food and shelter.

Invasive Aquatic plants*: Eichhornia crassipes, Pistia stratiotes* and *Salvinia molesta*

The three aquatic floating plants were accidental arrivals in Lake Naivasha*; Pistia stratiotes* (1960s)*, Salvinia molesta* (1962) and *Eichhornia crassipes (1988)* (Gherardi et al., 2011). After its first appearance in 1988 *E. crassipes* became dominant in the shallow parts of lake throughout the 1990s (Adams et al. 2002).

All the three the invasive aquatic floating plants form dense mats that lower dissolved oxygen in the water by blocking the air–water interface and by cutting light penetration to the water column, thus adversely impacting submerged macrophytes (Gherardi et al., 2011). Floating rafts in the shallow water also impede fish eagle foraging (Harper et al., 2002b). Floating mats have also adversely affected economic activities in the lake such as fishing and navigation by impeding vessel movements. Dead floating mats sink to the bottom of the lake thereby altering nutrient cycling (Gherardi et al., 2011) and deplete dissolved oxygen through increased Biochemical Oxygen Demand (BOD) during decomposition.

The invasive aquatic plants have also had positive impacts on the lake ecosystem. *Eichhornia crassipes* provides refuge to many invertebrates, specifically Oligochaeta, Insecta and Arachnida, while juveniles of *Procambarus clarkii* and *Micronecta scutellaris* find refugia amongst roots (Adams et al., 2002). These insects hide from predation under the thick fringes of *E. crassipes*. Between October and December 2000 however, the *E. crassipes* fringe effectively disappeared coincidentally with a P. clarkii population crash, so that by December 2000 few crayfish could be found (Harper & Mavuti, 2004).

The Common Carp, *Cyprinus carpio*

Common carp, *Cyprinus carpio*, has been extensively introduced around the globe and was accidentally introduced into Lake Naivasha in 1999 and quickly established itself becoming the dominant species in the catches by 2004 (Britton et al., 2007). Its introduction in many areas of the world has resulted in dramatic ecological disruptions due to its vigorous bottom feeding which disturbs sediments and disrupts vegetation (Titus et al., 2004). According to Britton et al., 2007, the catches of other commercial species such as *O. leucostictus* have markedly declined since the introduction of Common carp in Lake Naivasha. At the start of 2004, there was a marked shift in catches from tilapia to *C. carpio* and since this time, catches have generally comprised more than 90% carp. Before Common carp introduction, mean annual species composition of the finfish catch for the period 1987–2000 was *O. leucostictus* 71.7%, *T. zillii* 8.8% and *M. salmoides* 19.5% (Hickley et al., 2004). After Common carp introduction a big shift in catches occurred. Between 2002 and 2006, there was a change in contribution with a shift to *C. carpio* (51%), *O. leucostictus* (21.9%), *M. salmoides* (13.2%) and *T. zillii* (1.5%) (Ojuok et al, 2008). In the subsequent years the dominance of Common carp in the catches has been on the increase. Between 2007 and 2008, the catches were dominated by *C. carpio* (81.7%), *O. leucostictus* (9.7%), *M. salmoides* (8.3%) and *T. zillii* (0.3%). In 2015, the fishery was dominated by *C. carpio, O. niloticus*, *O. leucostictus* and *Clarias gariepinus* with contribution of 83.4%, 7.3%, 6.0% and 19% and 1.7% species, respectively (Njiru et al., 2017).

Being a voracious benthic forager, it was expected that Common carp introduction and establishment would lead to further macrophyte depletion. Instead regeneration has occurred, with areal cover in 2006 increasing to levels not observed in Lake Naivasha since the late 1980s. The direct and indirect effects of benthic foraging by carp had up to 2006 been insufficient in preventing macrophyte regeneration (Britton et al., 2007). The ecological mechanisms that enabled macrophyte regeneration to occur in conjunction with the establishment and subsequent fishery dominance of carp are, however, unclear.

The accidental introduction of Common carp into Lake Naivasha has resulted in the utilization of the benthic food which was underutilized before its introduction (Hickley et al., 2002). Stomach contents of carp and stable isotope analyses in a study by (Britton et al., 2007) revealed that benthic food is now being utilized. The introduction may also have prevented a surge in the population of *Procambarus clarkii* through predation and competition for food, mainly Oligochaetes. This is because the population of largemouth bass which used to reduce their population in the past through predation has remained low for a sustained period of time. In the study of Britton et al., 2007, fishes and crayfish were present in the diet of carp.

C. carpio has now replaced *Procambarus clarkii* as a keystone species in Lake Naivasha with expected further changes in the food web (Gherardi et al., 2011). Despite being less appreciated by consumers in comparison to the tilapias, the carp currently represents the only option for viable commercial fishery exploitation in Lake Naivasha (Britton et al., 2007).

Since its accidental arrival in Lake Naivasha, Common carp has had both beneficial and adverse ecological impacts on the lake. Common carp improved the lake fishery from near collapse in 2001 (Njiru et al., 2017). However, its dominance has had negative effects on other species which have steadily declined. The decline of other species may be attributed to poor water quality associated with the voracious benthic feeding habits of Common carp. Common carp feeds on benthic organisms by taking in sediments with food items and retains the prey while expelling the sediments through the gills. Carp feeding style uproots aquatic plants, stirs the sediments at the bottom, increases water suspended solids and affects water turbidity (Parkos et al., 2003). Increased turbidity decreases light penetration that is important for photosynthesis of submergent plants and phytoplankton. Reduced phytoplankton and aquatic plants reduces food-base for phytoplanktivore fishes such as *O. leucosticus* and herbivorous *T. zillii* (Njiru et al., 2017). Increase in turbidity affects the feeding ability of *Micropterus salmoides* and other visual feeders. Feeding style of *C. carpio* that disturbs the bottom also affects reproduction of other species such as *M. salmoides*, *O. niloticus* and *O. leucostictus* that construct their nest on the lake bottom (Njiru et al., 2017). The Common carp also offers stiff competition to *T. zillii* in terms of substratum like sand, pebbles and vegetation on which both of them lay their adhesive eggs. Common carp has a competitive advantage because it is non-selective on substratum type (Petr, 2000).

The African catfish, *Clarias gariepinus*

The African catfish, *Clarias gariepinus*, was accidentally introduced into Lake Naivasha through inflowing rivers, having escaped from fish farms. It was first recorded in the catches in 2012 (Njiru et al., 2017). From introduction, it seems to be slowly establishing itself in the lake. In 2015, it contributed 1.7% of the catches after *C. carpio* 83.4%, *O. niloticus* 7.3%, *O. leucostictus* 6.0%, *M. salmoides* 1.9% and *C. gariepinus* 1.7% (Njiru et al., 2017).

Conclusions and recommendations

Introductions of fish and other aquatic species have been carried out in different parts of the world for various reasons. These reasons include to boost the fishery of certain systems, occupy ecological niches to offer sport fishery and as a means of biological control. These introductions have had both negative and positive impacts on the new ecosystems with some leading to extinction of species in certain cases as is the case of haplochromines in Lake Victoria. In some cases, these introductions have had more positive than negative impacts on the fisheries by resulting in an increase in fish landings in some lakes as is the case of Nile perch, Nile tilapia in Lake Victoria and Common carp in Lake Naivasha.

Since the impacts of introduced species are unforeseeable, it would be prudent that introductions be based on scientific information on the systems before they are undertaken. Data on the ecological, social and economic impacts of the proposed fish on other ecosystems can be used as a guide on the possible implications of such introductions. Aquaculture facilities should be well managed to avoid or reduce the chances of fish escaping into the wild as is the case of the Common carp in Lake Naivasha. Finally, introduction of any species into any system should be treated as the last resort in the fisheries management options. This is because introductions are almost irreversible even when the impacts are negative and destructive to the ecosystem upon which the introduction was done.

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