Deleterious Effects of Non-native Species Introduced into Lake Victoria, East Africa

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Abstract

Lake Victoria, in East Africa, has suffered from introductions and invasions of non-native species such as *Lates niloticus*, various tilapiine species, and *Eichornia crassipes* since the 1950s. These have had a devastating effect on the natural biological communities. This paper reviews the effects of the introductions on ecology, environment, fisheries and the local human population.

Introduction

Lake Victoria is the second largest freshwater lake in the world and the largest of its kind in Africa. The lake is shared by Kenya (6%), Tanzania (51%), and Uganda (43%). The local communities in the catchment have relied on Lake Victoria for their livelihood for centuries. The lake provided about 200 000 tons of harvestable haplochromine fishes in the early 1970s. In the last three decades, however, the lake's ecosystem has been severely damaged by human activities and environmental changes, including the introduction of exotic species, invasion of water hyacinth (*Eichornia crassipes*), and increased nutrient load from farming activities.

Introduction of foreign species into new habitats is either accidental or deliberate. There are many examples of introduced species becoming invasive and causing damage to native populations of wild and domesticated organisms. The introduction of non-indigenous species to Lake Victoria is seen as the main factor responsible for the changes in its ecosystem (Twongo 1995).

The effects of a species introduction are frequently unpredictable, as the new species has to adapt to conditions that may differ completely from those in its native range. Fish assemblages receiving an introduction may be altered through competition, direct predation or hybridization. Despite some arguably positive effects on biodiversity at the local level, there is an overwhelming body of evidence pointing to the profoundly negative effects of introductions on species and on genetic diversity at both local and regional levels. Introductions can lead to severe disruptions in ecological communities and the genetic diversity of indigenous species.

The lake has undergone remarkable changes since the 1920s. The use of non-selective fishing gear, extreme changes in drainage basin vegetation, industrialization, agricultural development, and introductions and invasions of exotic species are some of the factors that have led to the destruction of native and endemic species (IUCN 1999). The Lake Victoria ecosystem has been particularly affected by introductions of the Nile perch (*Lates niloticus*) during the 1950s (Ogari 1984), *Tilapia* species (*T. zillii* and *T. rendalii*) and *Oreochromis* species (*O. niloticus* and *O. leucostictus*) in 1951 (Welcomme 1964; Ogari 1984; Ogutu-Ohwayo 1990a), and the invasion of water hyacinth (*Eichornia crassipes*) in 1988 (Mallya 1998). Scientists, fishers and environmentalists have decried the loss of Lake Victoria's native species, while others value some of the introductions. Gibbon (1997) noted that such a productive fishery followed the introduction of the Nile perch that it was referred to as a 'saviour'. However, the saviour has profoundly altered the lake's ecosystem, certainly to the detriment of some species (Goldschmidst et al. 1993).

This review discusses the deleterious effects of the introductions and invasion on non-native species to Lake Victoria. The effects reviewed are ecological, environmental, economic and socio-economic.

Ecological Effects

Competition

In the early 1950s, signs of a collapsing tilapiine fishery were evident to fisheries biologists and managers (Kudhongania and Chitamweba 1995). This led to the introduction of exotic species to Lake Victoria in order to increase exploitable fish stocks and thus reduce fishing pressure on the two native species, *O. esculentus* and *O. variabilis*. Four species (*T. zillii*, *T. rendalii*; *O. leucostictus* and *O. niloticus*) were introduced in the early 1950s (Welcomme 1967). The introduced tilapias quickly established themselves in the lake and began to appear in commercial landings from 1959 onwards (Twongo 1995). However, the interactions between native and exotic tilapias in Lake Victoria were considerably more complex than had been originally anticipated (Welcomme 1966, 1967).

There was clearly no overlap between the diet of adult *O. esculentus* and any of the exotic species (Loissele 1997), but significant overlap was found between the diet of adult *O. leucostictus* (introduced) and *O. variabilis*. Moreover, examination of

the diets of juveniles revealed extensive overlap between the diets of *O. esculentus* and all three exotics (Loissele 1997) (Figures 1a and 1b).

There is some evidence that diets of some aquatic invertebrates and birds in Lake Victoria have also changed following the introduction of the new fish species and the decline in indigenous species (Goudswaard and Wanink 1994). For instance, the pied kingfisher (*Ceryle rudis*) that fed mainly on haplochromines, changed to a diet composed of almost 100% *Rastrineobola argentea*. Before the introductions, only the young nesting pied kingfishers took *R. argentea* as their primary food.

Competition is not only reflected in trophic interactions but also in other ecological factors such as habit preference and breeding/spawning areas. Ogutu-Ohwayo (1990c) reported that there was a clear overlap in habitat and nursery area preference between *O. variabilis* and the introduced *O. leucostictus*, *T. rendalii* and *T. zilii*. Direct observation of juveniles revealed that *T. zillii* was clearly dominant over *O. variabilis* (Fryer 1961). There was indirect evidence that juveniles of *O. leucostictus* were crowding out *O. variabilis* fry from their traditional nursery areas (Seehausen 1996). Welcomme (1967) reported that *T. zillii* dominated the catches in the Lake that were previously dominated by *O. variabilis*. A competitive interaction between the introduced tilapiines and the indigenous species appeared to be the most plausible explanation for the decline in the latter species (Fryer 1961; Welcomme 1967).

Hybridization

Fishes are generally more plastic in their potential for interbreeding than other animals. In Lake Victoria, the introduction of *O. niloticus, O. leucostictus* and *T. zillii* resulted in hybridization between *O. variabilis* and the introduced *O. niloticus* (Fryer 1961; Welcomme 1967). The phenomenon might also have contributed to the disappearance of *O. variabilis* from some locations in the lake. Welcomme (1964, 1966) documented the presence of such hybrid fry in the lake within the first decade of introduction. As *O. variabilis* numbers declined and *O. niloticus* numbers increased, the likelihood of the less abundant of the two species being able to find a co-specific spawning partner likewise diminished. Such a situation favors hybridization which, in the

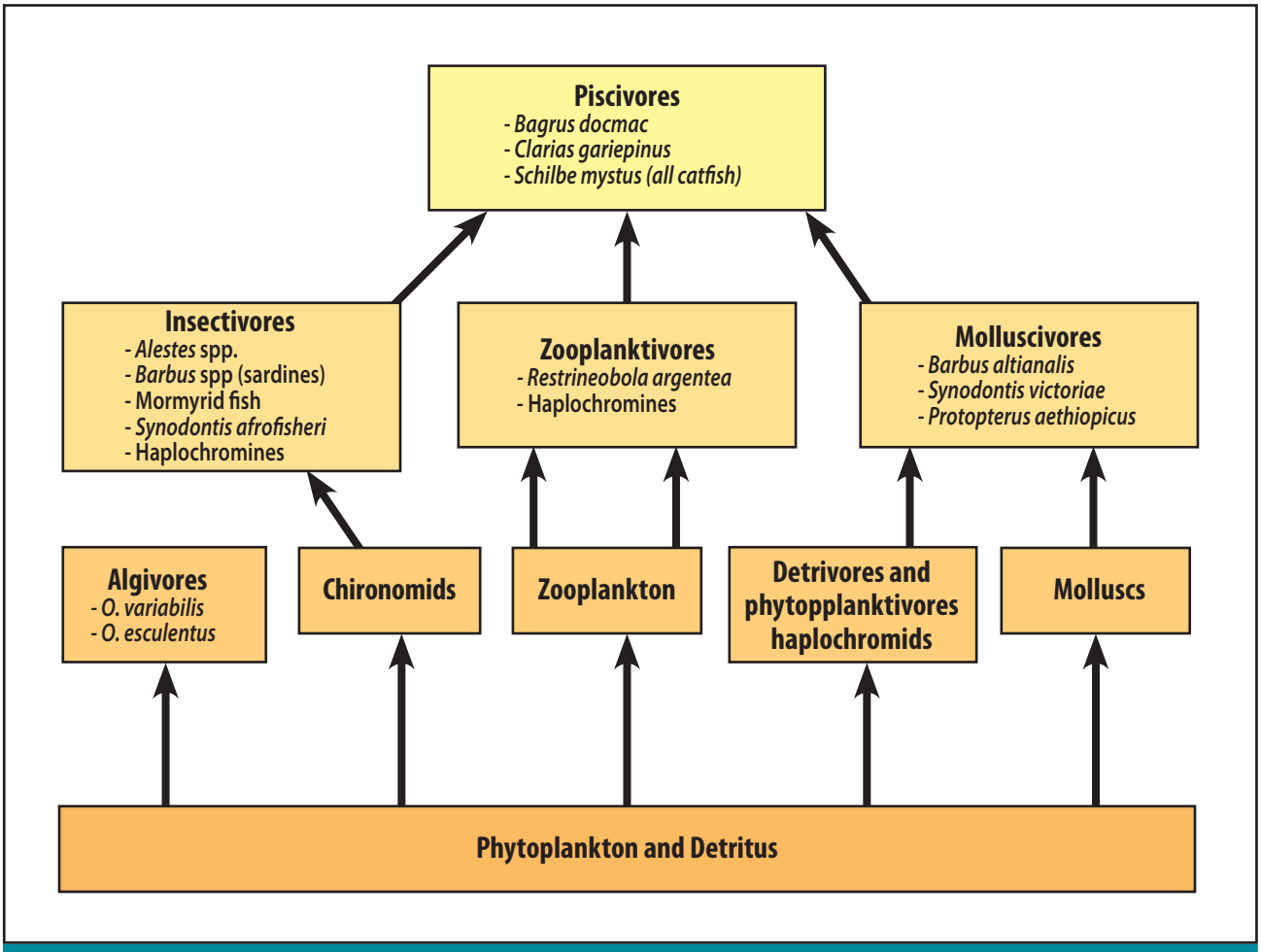

Figure 1a. Food web in Lake Victoria prior to introduction of the Nile perch (Source: Witte et al. 1992).

absence of significant immigration of representatives of the less abundant species, leads to its eventual disappearance. Data from tagging experiments (Fryer 1961) suggest that adult *O. variabilis* tend to remain within a relatively restricted area. Such sub-populations would clearly be at risk from the consequences of this sort of genetic introgression. The successful naturalization of *O. niloticus*, *O. leucostictus*, and *T. zillii* to the lake resulted in *O. variabilis* moving to the edge of extinction.

Predation

The Nile perch is a predatory fish species and it was introduced into Lake Victoria to feed on the small, abundant, but commercially unimportant haplochromines, which constituted 80% of the fish biomass in the lake at the time (Kudhongania and Cordone 1974), and create a profitable fishery. Although introduced in the 1950s, it took a long-time for the Nile perch population to expand and it was not a significant fishery until 1971 (Jackson 1971). Since then the complex ecosystem of Lake Victoria has been irreversibly changed by the predation of the introduced Nile perch (Barel et al. 1985; Ogutu-Ohwayo 1990a; Witte et al. 1992). It has demonstrated its voracious feeding habit not only on the small haplochromines, but also on other commercially valuable fish, such as tilapias (Moss 1998). The perch has apparently reduced fish stocks so much that it now takes its own young and freshwater prawns (*Caridina niloticus*) as a food source (Moss 1998; Ogutu-Ohwayo 1990b; Mkumbo and Ligtvoet 1992; Mkumbo 2002; Mhitu and Chande 2003).

The Nile perch is reported to be responsible for the extinction of over 300 species of haplochromine cichlids (Barel et al. 1985; Ribbink 1987), the largest single recorded vertebrate extinction attributable to specific human actions on earth and the largest single vertebrate extinction since the Cretaceous Terminal Event (Loissele 1997). The Nile perch in Lake Victoria has also virtually eliminated other endemic fish species such as *O. esculentus* and *O. variabilis*, resulting in a loss of genetic diversity accompanied by a loss of some trophic levels (Ogutu-Ohwayo and Hecky 1991). The transformation of the fish community coincided with profound eutrophication resulting in algal blooms, fish kills and hypolimnetic anoxia, which might be related to alterations of the lake's food web (Figs 1a and 1b).

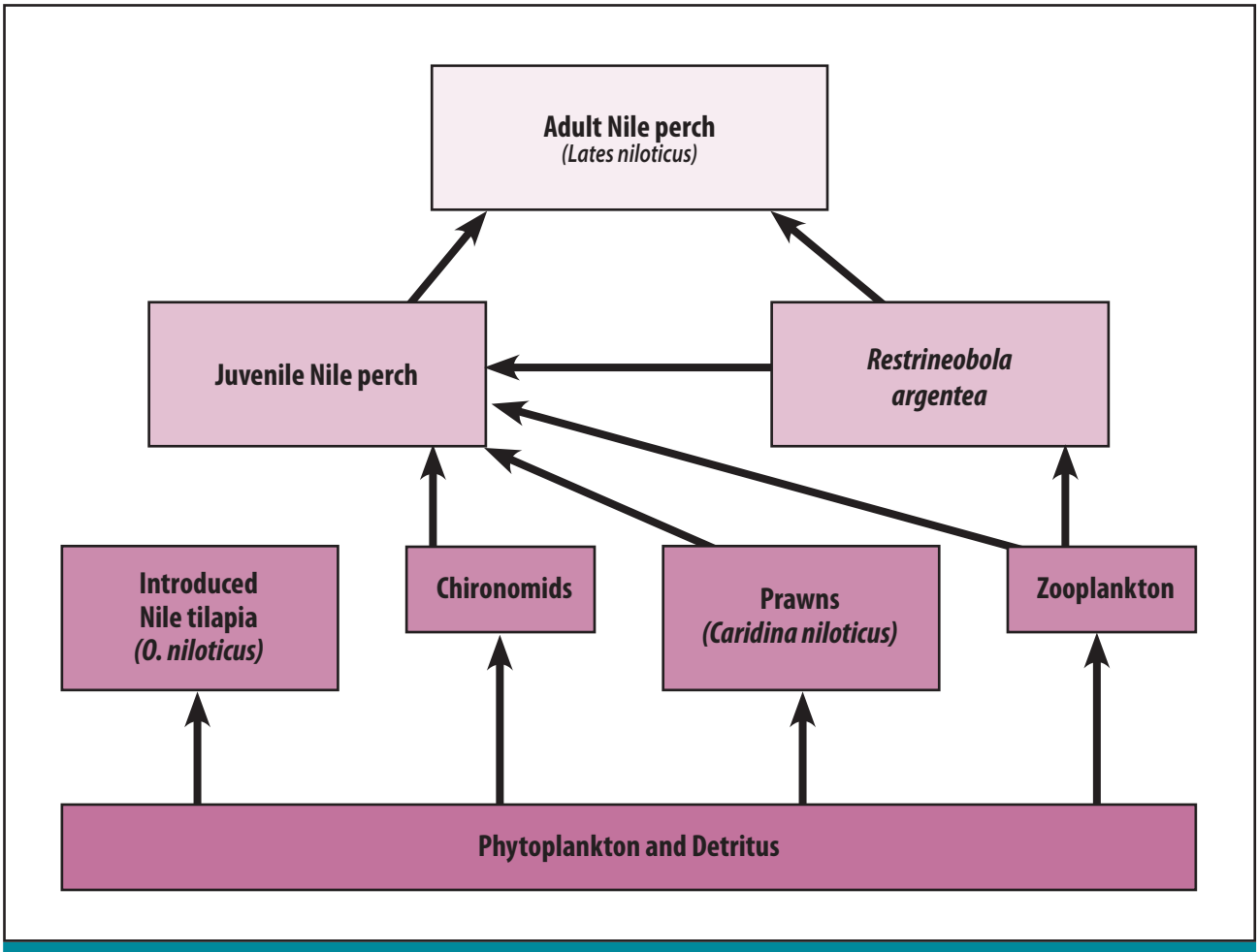

Figure 1b. Food web in Lake Victoria after the introduction of the Nile perch (Source: Witte et al. 1992).

Diseases and other health hazards

Diseases often result after the introduction or invasion of organisms from one ecosystem to another. In some cases, the introduced individuals carry disease and parasites from the previous environment to the new ecosystem and transmit them to the native species. So far, there is no evidence of a specific disease brought in by exotic species that were introduced into Lake Victoria. However, the introduction of Nile perch and the invasion of water hyacinth in the lake are blamed for accelerating the spread of some diseases which prevailed in the lake region but at a low level. The Nile perch is believed to have caused the extinction of several hundred species of haplochromines (Seehausen 1996) with a consequent alteration of the food web structure of the lake as discussed. *Astatoreochromis alluadi* is one of the haplochromine species affected by the Nile perch and it was reported by Slootweg (1987) to be the main predator of the snail that is a vector of the bilharzia parasite. The predation on *A. alluadi* by the Nile perch reduced its numbers in the lake and consequently increased the number of the biomphalaria snails in and around the lake.

The invasion and spread of the water hyacinth (a preferred habitat for snails) has created a suitable environment for biomphalaria snails to reproduce and multiply and, hence, accelerated the spread of bilharzia in the lake zone. Water hyacinth also provides a suitable habitat for the mosquito that is the vector of malarial parasites.

It should be added that there has been a controversy over the role the introduced species have played. Some scientists directly associate the mass extinction of haplochromines and native tilapia species with the introduction of Nile perch and non-native tilapiines (Ogari 1984; Ogutu-Ohwayo 1984; Hughes 1986; Witte et al. 1992), while others suggest that this was due to a combination of changes that occurred to the lake and not simply to the introductions alone.

Environmental Effects

The increased catch of Nile perch from Lake Victoria resulted in the development of a number of local processing industries. Untreated effluents from these industries and other local manufacturing plants discharge into the lake and cause pollution. The Nile perch boom provided new jobs and the total yield of the fishery increased five times between the 1970s and 1990s (IUCN 1999). This led to a dramatic increase in population around the lake, now estimated at 30 million. Human activities such as farming, application of fertilizers, production of domestic wastes and cooking-fire ash, and fishing activity led to excessive nutrient run-off and lake eutrophication. As the Nile perch is an oily fish that requires more firewood for drying than less oily fish such as tilapia, pressure was placed on local resources leading to deforestation and consequent soil erosion.

Water hyacinth (*E. crassipes*) was first reported in Lake Victoria in 1988 (Mallya 1998). Since then it has been reported from many locations all around the lake. The weed is responsible for reducing oxygen levels and nutrients in the water of sheltered bays that are breeding and nursery grounds for tilapia.

Effects on the Lake Fishery

The Nile perch was introduced into the lake to enhance the fishery and make large fish available to millions of people living on its shores. Though the Nile perch was rarely seen for twenty years after its release, it is now a dominant species. The fishery of Lake Victoria has, as a consequence, undergone substantial changes (Reynolds 1988). The Nile perch has contributed to the decline of the indigenous tilapia fishery (Riedmiller 1994), and reduced other species to remnant populations or caused their extinction, and itself become the basis of a large export industry.

According to Fryer (1961), the early gillnet fishery of mesh size 10 cm introduced in 1956 in Lake Victoria was based on *O. esculentus* and *O. variabilis,* and it peaked in 1958. The catches of *O. esculentus* and *O. variabilis* declined during 1959 and 1960, indicating that the stocks had also declined. This led to the introduction of the Nile perch and non-native tilapiines that performed better than the native species but was responsible for the decline of the fish species diversity (Ogari 1984; Ogutu-Ohwayo 1984, 1990a, 1990b, 1990c; Hughes 1986; Witte et al. 1992).

Ochumba et al. (1994) documented the consequences that are detrimental to the lake's biodiversity and that led to a change from a multispecies fishery to one based on only two major exotic species, namely *L. niloticus* and *O. niloticus,* and one endemic species, *R. argentea*. A fishery that depends on a species that is a top predator and whose current production depends on cannibalism and relatively few other prey species is inherently unstable, especially with the physico-chemical changes occurring in the lake (Moss 1998).

Socio-economic Effects

In addition to biological and ecological effects, introductions also have socio-economic implications. In the 1980s, when the Nile perch fishery started, the riparian communities of Lake Victoria regarded it as food for poor people (Bwathondi 1990). However, a decline of the native tilapiine fishery and development of the Nile perch processing industry with access to external markets caused the price of Nile perch to shoot up. It has become unaffordable for low-income people (the majority) and is now food for rich people and external markets.

The native fish of Lake Victoria used to be harvested by small-scale fishers, and processed and traded by women for the local communities. The nutritional and economic benefits went to the lakeside communities. The export of Nile perch has decreased the supply and raised the price of the remaining types of fish in the local markets, making them less affordable for the local communities (Abila and

Jansen 1997; Onyango 2003). In the 1980s, the 'punk' (the skeletons left after removing the flesh of the Nile perch) were a significant source of food and protein for the poor in the lake region (Onyango 2003). Today, they are scarce because they are used in the manufacture of animal feed. Deprived of work and unable to afford this higher priced (though less palatable) catch, local people face a serious nutritional predicament. The dominance of Nile perch in the Lake Victoria fishery is believed to have had a negative effect on the food security and nutritional status of 30 million people living around the lake (Onyango 2003).

The introduction of Nile perch has accelerated another set of economic problems. The fishery of Lake Victoria, pre-introductions, was based on small cichlids whose capture required small mesh gill nets. The need for the fishers to re-equip with nets of the appropriate size to capture Nile perch and shift from subsistence fisheries to more commercial operations for export was beyond the scope of many resource-poor farmers.

Conclusions and Recommendations

The environmental, biological, fishery and socio-economic effects of introduced/invasive species can be very severe, as has been witnessed in Lake Victoria. The problems in the Lake Victoria ecosystem result directly from human activity. The Nile perch and other non-native tilapiines simply took advantage of an environment that evidently suited them, to the detriment of native species. This review of the impacts of introductions of new species indicates that any further introductions to the lake, or to any other ecosystem, should be avoided. Where an introduction is deemed necessary, intensive studies should be done in advance on the biological and ecological behavior of the species to determine the potential impacts. Monitoring programmes should then measure the effects of introductions on local biodiversity to provide information that may help people recognise threats at an early stage.

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