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Biological diversity of the Yala Swamp lakes, with special emphasis on fish species composition, in relation to changes in the Lake Victoria Basin (Kenya): threats and conservation measures

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Abstract. During the second half of the last century, the Lake Victoria ecosystem has undergone drastic ecological changes. Most notable has been the decline in the populations of many endemic cichlid fishes. The lake has lost nearly 200 haplochromines and one tilapiine, *Oreochromis esculentus*. The above changes have been attributed to effects of species stocking and, in particular, from predation pressure by the introduced Nile perch, *Lates niloticus*. Other factors that have led to the decline of the endemic species include intensive non-selective fishing, extreme changes in the drainage basin, increased eutrophication, and the invasion of the lake by the water hyacinth, *Eichhornia crassipes*. However, the remnants of some species that had disappeared from Lake Victoria occur abundantly in the Yala Swamp lakes (Kanyaboli, Sare and Namboyo). This paper discusses the biodiversity of the swamp and the three lakes and gives suggestions for their conservation.

Introduction

Biological diversity is defined as: ''the variability among living organisms from all sources including *inter alia* terrestrial, marine, freshwater, other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species and of ecosystems'' (Gray 1997). Threats to biodiversity are a direct result of human population and demographic trends. The world population has more than doubled since World War II and was expected to increase from 5.5 billion in 1992 to 8.5 billion by 2025 (Anonymous 1993). Within the past few hundred years, humanity has had a profound and, in some cases, irreversible effect on the environment and on individual species. As the human population has increased, more and more land has been cleared for agriculture, settlement and industry, and species have been collected from the wild at an unsustainable rate. Thousands of species worldwide are under threat from overuse, loss of habitat and environmental pollution. Since species in an ecosystem are interdependent, the loss of one species can lead to the disappearance of many others (UNEP 1991).

The threats to aquatic systems include habitat loss, global climatic change, overexploitation and other effects on fishing, for example, pollution, eutrophication, species introductions, watershed alterations and physical alteration of the aquatic system. The most critical threat to aquatic environments is habitat loss and so the most effective way to conserve their biodiversity is to prevent the conversion or degradation of the habitat (Heywood and Watson 1995). East African countries contain some of the best understood ecosystems in the tropics, and yet habitat destruction and loss of biodiversity in these countries are occurring at an alarming rate (Harper and Mavuti 1996). There are many plants and animals in tropical wetlands whose fascinating life histories are poorly known and which yet are on the edge of extinction. The human race has a vital role to play in the future of the Earth because our own future depends on it. Mankind has a responsibility to respect and protect the living resources on planet Earth.

Since the middle of the last century, 1354 introductions of 237 fish species into 140 countries have been documented worldwide (Welcomme 1988). Africa has experienced only 147 introductions (11% of the total) of 50 fish species (21% of the total), 23 of these from outside Africa, although African fish have been exported widely elsewhere. The impact of introductions in Africa has perhaps received a high public profile on account of the concern about the effects of the Nile perch on endemic fishes in Lake Victoria. The stated reasons for introductions include aquaculture, improving fisheries, sportsfishing and control of other fish (Pitcher and Hart 1995).

The Lake Victoria example

Lake Victoria, which is Africa's largest freshwater lake, has a densely populated watershed and there is strong evidence to indicate that its ecosystem has been impacted by man's activities, including fishery exploitation, exotic fish introductions, eutrophication and introduction of ornamental macrophytes (Kudhongania et al. 1996). The lake has undergone significant changes during the past 30 years and is now in a transient state that causes considerable concern (Hecky and Bugenyi 1992).

Introduction of exotic fish species

When two indigenous *Tilapia* species declined from the commercial catches, four exotic tilapiines were introduced into Lake Victoria in the 1950s (EAFFRO 1964) in order to stimulate the commercial fishery. A huge predaceous fish, the Nile perch (*Lates niloticus*) from the Nile river, was later introduced to improve fishing and to convert the abundant haplochromine biomass into table fish; it provoked mass extinction of native fish which were an important part of the entire lake ecosystem. The lake's original complement of more than 500 native fish supported a traditional shore fishery in the lake-side countries – Kenya, Uganda and Tanzania (Kaufman 1989). The above exotic fish introductions have had significant impact on the ecology and biodiversity of Lake Victoria.

Table 1. Fish species composition of Lake Victoria in the 1960s.

Fish species	Percentage contribution to biomass	Percentage contribution to annual catch
Haplochromines	85.3	22.4
Bagrus docmak	5.7	29.5
Claria gariepinus	3.7	7.5
Tilapiines	2.8	23
Protopterus aethiopicus	1.3	9.2

Sources: Ogutu-Ohwayo (1990), Kudhongania et al. (1992).

Nevertheless, there were also some positive effects of the Nile perch boom: lake-wide fish catches increased substantially from 100 000 ton in 1980 to over 450 000 ton in 1989 (Reynolds et al. 1995); the shift to Nile perch fishery (more off-shore, wider meshes) released the fishing pressure on the Nile tilapia stocks, which had been overfished, resulting in a recovery of the stocks and better catches in later years (Ligtvoet et al. 1995), while fish factories based on the Nile perch have employed many people in the lake shore towns.

Today, a local economy based on native species has been displaced by an export-oriented 'exotic' industry that has destroyed the resource and largely bypassed the local people. Even the future of the perch has been called into question. Although the perch is known to prefer the shrimp *Caradina nilotica* and also depends substantially on the cyprinid *Rastrineobola argentea* (Mkumbo and Ligtvoet 1992), it has also been reported to feed on its own juveniles. Currently reports have indicated a decline in the size of Nile perch landed, probably due to overexploitation.

In the 1960s, the fish species of Lake Victoria was diverse and dominated by the haplochromines (Table 1). *Oreochromis esculentus* and *O. variabilis* were the most important commercial species, followed by *B. docmak, Clarias gariepinus, P. aethiopicus, Barbus* spp. and S*chilbe mystus*. *Labeo victorianus* was the most important commercial species in the affluent rivers (Ogutu-Ohwayo 1990).

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. It has been suggested that reduced grazing pressure may be partly responsible for the increased phytobiomass and widespread anoxia in the lake (Hecky and Bugenyi 1992; Muggidde 1992). Currently the fisheries of Lake Victoria rest on only three species: The Nile perch, *Lates niloticus*, the minnow, *Rastrineobola argentea*, the tilapias and a few haplochromines (Rabuor and Polovina 1995).

Invasion of the lake by water hyacinth

Lake Victoria was invaded by the water hyacinth (*Eichhornia crassipes*, Martius) in 1990. While the introduction of the weed in the lake may have been accidental, the water hyacinth was originally transported from its native home in South America to Africa to be used as an ornamental plant (Twongo et al. 1992).

Eichhornia crassipes has spread to many parts of the lake shores and proliferated in inshore areas with high nutrient content (Twongo et al. 1992). The inshore areas are where many fish species breed, nurse, shelter and feed. Proliferation of the water hyacinth leads to reduced oxygen due to its respiration and shading of solar radiation, thereby reducing photosynthesis (Kudhongania et al. 1996). Other effects of the weed include reduced pH due to increased carbon dioxide, increased water clarity due to reduced phytoplankton, reduced floral and faunal diversity due to low oxygen level and increased loss of water from the lake by evapotranspiration. *Eichhornia crassipes* has been described as the world's worst aquatic weed (Harley 1990). In Lake Victoria the weed imposes serious uncertainties for future fish production and biodiversity.

Although water hyacinth has been blamed for reduction in fish catches and the spread of diseases such as malaria and bilharzia, the weed has some positive attributes. For example, catches of *Clarias gariepinus*, *Protopterus aethiopicus* and *Momyrus kannume*, which decreased in the 1980s in the lake, have increased tremendously following hyacinth infestation (Bugenyi and Van der Knaap 1998; Njiru et al. 2000; Ogari 2000).

Eutrophication

Eutrophication is mainly due to urban, industrial and agricultural activities around the lake region. Urban and industrial expansions along the lake shores have increased the volume of sewage, garbage and other effluents which end up in the lake (Bugenyi 1987). Industrial, domestic and agricultural runoff have doubled the biological productivity of Lake Victoria during the last 30 years (Hecky and Bugenyi 1992; Muggidde 1992). Higher biological productivity is largely responsible for the increased algal biomass, leading to deoxygenation of deep water.

Agricultural activities around the lake have involved vegetation clearing, deforestation, bushfires and draining of swamps for growing various crops, all leading to extreme changes in the drainage of the basin and accelerated soil erosion (Bugenyi 1987). In addition, pesticide fertilizers and other agro-chemicals are increasingly applied and some eventually find their way into the lake system.

Fisheries exploitation

One of the human activities known to have had significant impact on Lake Victoria fauna is the exploitation of a multispecies fishery. In the absence of any effective controls for gillnet mesh sizes, entry of fishermen, canoes or fishing gear per canoe, fishing pressure eventually becomes detrimental to the fish stocks. For example, the intensive gill-netting of gravid *Labeo victorianus* during breeding migrations wiped out the *Labeo* fishery (Garrod 1961; Cadwalladr 1965). The capture of immature fish and interference with their breeding and nursery strategies have also had detrimental effects on the fish stocks (Welcomme 1964).

The recent changes in the fisheries of Lake Victoria exemplify the detrimental effects of man on the environments of the planet Earth (FAO 1994). The fish fauna of this lake once consisted of numerous species of the haplochromines and two native tilapiine species, *Oreochromis esculentus* and *O. variabilis*. Other tilapiine species occurring in the lake were: *O. leucostictus*, *O. niloticus*, *Tilapia rendalli* and *Tilapia zillii*, which were introduced in the lake in the 1950s. Of the introduced tilapiines, *O. niloticus* still occurs in the lake in reasonable numbers and is one of the three main species in the current fisheries. The remaining tilapiine species, although still present in the lake, occur in low numbers (SeeHausen 1996). Other non-cichlid species that occurred abundantly in the lake included *Alestes* sp. (*Brycinus*), *Labeo victorianus*, *Bagrus docmak*, *Clarias gariepinus*, *Momyrus kannume* and *Protopterus aethiopicus* (Balirwa 1995). The above fishery now rests on only three species: the Nile perch, *Lates niloticus*, the minnow, *Rastrineobola argentea*, the Nile tilapia (*Oreochromis niloticus*) and a few haplochromines (Kaufman 1989; Rabuor and Polovina 1995).

Although the above listed fish species disappeared from the main Lake Victoria, a recent survey of the Lake Victoria basin revealed that some of the species which were reported to have disappeared from the main lake currently occur in reasonable numbers in some small satellite lakes within the Yala Swamp, namely: Lake Kanyaboli, Lake Sare and Lake Namboyo (Species Survival Programme – SSP 1994). Despite the fact that the three lakes are the only source of protein to the local communities, ecological studies on them are scarce and no meaningful conclusions can be drawn from such studies for the conservation of the lakes. Such studies include those of Okemwa (1981) on the preliminary survey of the fisheries and limnology, Mavuti (1989) on the limnology, Opiyo (1991) on the feeding ecology of *Oreochromis esculentus*, and Aloo (1999) on the survey of the biodiversity. There are no detailed studies on the ecology of the fish species and other aspects of the lake ecosystem. Such studies should be carried out to provide information required for the conservation of these lakes.

The Yala Swamp

There are many seasonal and permanent swamps within the Lake Victoria basin, especially along the river mouths and near the lakeshore. The two largest swamps on the Kenyan side of the lake basin are the Yala and the Nyando swamps. Yala Swamp (Figure 1) lies partly in Siaya District in Nyanza Province. The swamp is bounded by Hwiro and Nzoia River to the north and Yala River to the south. It is separated from Lake Victoria by a sand bar through which the Yala River cuts in many deltaic outflows into the Lake. Yala Swamp is a typical example of valley swamps which were formed in the Pleistocene by water level changes and river flow reversal, leading to deposition of silts, infilling of former lakes and colonization by rooted plants: this has often led to complex mosaics of plant communities. Valley swamps are very susceptible to draining by man and many have been converted to agricultural land in the last four decades, losing some of the unique vegetation types (Harper and Mavuti 1996).

Fish species composition

This swamp, like the surrounding lakes, is inhabited by many fish species, all of which breed here. These include: *Clarias gariepinus*, *Protopterus aethiopicus*, *Labeo victorianus* and *Barbus* spp., but they occur in very low numbers. *Protopterus* is common only in the periphery of the swamp. The stagnant waters of the swamp do not contain as many fish as originally thought because dissolved oxygen levels are very low (less than 4 mg O_2 l^{-1}).

Flora and other fauna

Besides being an important ecosystem, this swamp acts as a natural filter for a

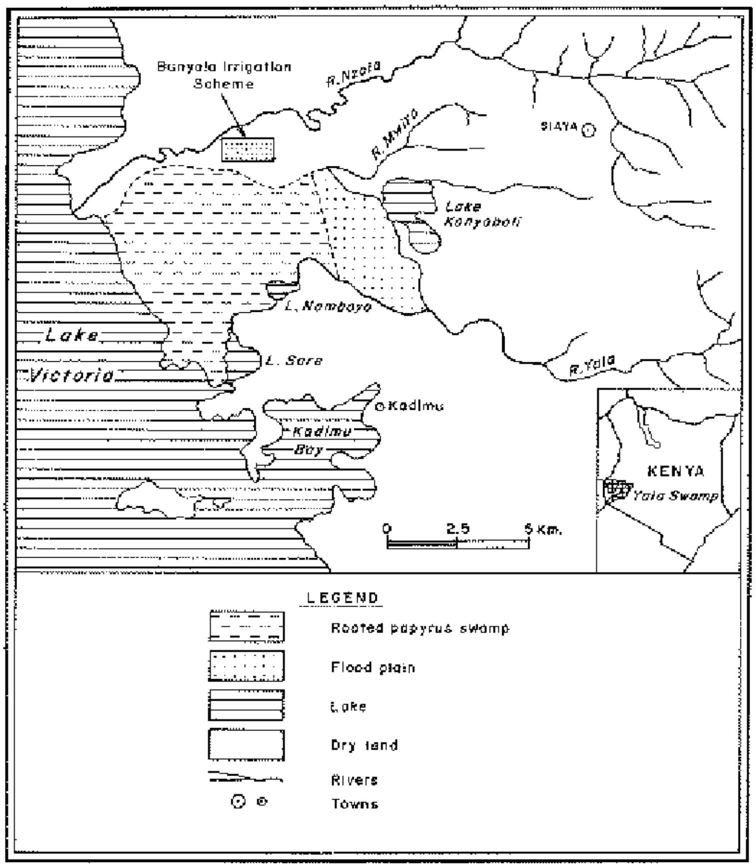

Figure 1. Geographical location of the Yala Swamp and associated lakes.

variety of biocides and other pollutants from the catchment area (Mavuti 1989). The common rooted vegetation of the Yala Swamp are *Cyperus papyrus* and *Phragmites mauritianus*. The shore is lined with a wide belt of *C. papyrus* and swamp grasses, while further inland the swamp becomes a dense mixture of *Phragmites* and papyrus reeds. The macrophytes that surround the swamps are of considerable ecological value, because they act as nursery grounds for young fish, and harbour various animal groups including annelids, insects, molluscs, reptiles, birds and mammals (Opiyo 1991). A rich community of invertebrates and birds is found among the Yala River outlets into Lake Victoria. The aquatic nymphs of mayflies (Ephemeroptera), dragonflies (Odonata) and stoneflies (Plecoptera) are also common in the gravel substratum of the rivulets. *Phragmites* strands from the swamp are used for making fish traps while papyrus reeds are used for making baskets, mats and for thatching by the local people (Mavuti 1989).

Threats

In 1963, the Kenya Government submitted a request for assistance to the United Nations Development Programme (UNDP) in carrying out pre-investment surveys and pilot irrigation schemes for the reclamation of the Yala Swamp. By 1966 a plan of operation was initiated, particularly the diversion of the Yala River along the southern edge of the swamp for a distance of about 7.5 km, the construction of the 200 ha scheme originally envisaged and the establishment of another 200 ha pilot scheme in the swamp. Topographical and engineering surveys were added for the purpose of determining the possibility of utilizing Lake Kanyaboli as a storage reservoir and for designing a dyke along the shores of Lake Victoria to enable the western end of the swamp lying below Lake Victoria water level to be reclaimed by pumping out water (FAO/UNDP 1965). Currently, part of the swamp has been reclaimed for agricultural use, an issue that created controversy between environmentalists and government officials. To the environmentalist, the Yala Swamp is an important ecosystem for various species of birds and mammals such as the Sitatunga (*Tragelaphus spekei*), which are unique to this wetland (Opiyo 1991). To government officials and farmers, the swamp is a rich agricultural ground on which a variety of food crops and fruits thrive. Reports have also indicated that there are perches of the water hyacinth (*Eichhornia crassipes*) within the swamp (Species Survival Programme – SSP 1994). Unfortunately, the government of Kenya has recently put aside Ksh. 200 million to drain the swamp for agricultural purposes. The report added that when completely drained and utilized agriculturally, the swamp will be the granary of the entire Western Kenya region (Anonymous 2001).

Satellite lakes

Lake Kanyaboli

This is a small lake with an area of 10.5 km^2 and reaches a maximum depth of 3 m

Table 2. Average readings of physico-chemical parameters of the three lakes.

Waterbody	DO ($mg\,l^{-1}$)	Area (km^2)	Depth (m)	Conductivity ($\mu s\ cm^{-1}$)	pH	Transparency (m)	Temp (°C)
Kanyaboli	7.3	10.5	3.0	600	7.7	0.3	25.8
Sare	8.1	5.0	5.0	150	7.6	0.25	26.4
Namboyo	4.8	0.01	20.0	62	6.3	–	–

Sources: Okemwa (1981), Species Survival Programme – SSP (1994), Aloo (2000).

towards the north (Figure 1). It is located on the northeastern extremity of the Yala Swamp at an altitude of 1156 m a.s.l.

Before the construction of a diversion canal, the Yala River used to flow through the eastern swamp into Lake Kanyaboli before dispersing into the main swamp. After 1970, the lake was separated from the swamp by a silt-clay dyke but connected to it by a drainage canal. After the reclamation of the Yala Swamp, the Yala River was diverted and a feeder canal constructed to replenish the waters of Lake Kanyaboli. However, recent reports indicate that the canal has been destroyed by livestock and very little water now reaches this lake (Species Survival Programme – SSP 1994). The physico-chemical parameters of the lake were observed to be unnatural due to lack of inflowing waters (Table 2).

Fish species composition

The fish fauna of Lake Kanyaboli is unique, as it is made up of the fish species which populated Lake Victoria before the introduction of the Nile Perch (Mavuti 1989). The indigenous fish species *Oreochromis esculentus* and *O. variabilis*, which formed the mainstay of the tilapia fishery in Lake Victoria in the 1950s and 1960s but are now absent, are found in reasonable numbers in this lake (Mavuti 1989; Opiyo 1991). The most important fishery of this lake is that of the tilapiines including *Oreochromis esculentus*, *O. leucostictus*, *O. variabilis* and *O. niloticus*. *Oreochromis esculentus* forms the backbone of the commercial fishery in the lake with an average catch per canoe of 26 kg (Opiyo 1991). The abundance of *O. esculentus* in Lake Kanyaboli may be attributed to the absence of the voracious predator, *Lates niloticus* (Opiyo 1991).

The second most important fish species are the haplochromines. Kaufman (1989) reported that there are about 5–6 different haplochromine species in the lake. These include: *Haplochromis maxillaris, Astatoreochromis alluaudi, Xystichromis phytophagus, Haplochromis* sp. ('dwarf bigeye'), and *Astatotilapia nubila* ('black haplochromis') (Kaufman and Ochumba 1993). Two haplochromine species, *Astatoreochromis alluaudi* and *Astatotilapia nubila*, still occur abundantly in Lake Victoria. Lake Kanyaboli is also an important nursery and refuge area for *Protopterus aethiopicus* and *Clarias gariepinus*, which rank third and fourth in the fishery of the lake. It is therefore imperative that proper management and conservation measures be taken to protect the fishery of Lake Kanyaboli from any future environmental catastrophe.

The fishery of Lake Kanyaboli is canoe based, using mainly gillnets of 4″ and 5″ mesh sizes. Other fishing methods include beach seining using 2-in. mesh nets and hook and line. The last method is mainly used to catch haplochromines and *Protopterus*. However, when gillnets are used then tilapias and *Clarias* form the bulk of the catch, while beach seining only catches tilapias and haplochromines. Lake Kanyaboli produces about 250 ton of fish composed of approximately 50% *Oreochromis esculentus* and 40% *O. niloticus*. The catches have gone down recently due to poor management of the fishery.

Flora and other fauna

Lake Kanyaboli is surrounded by a thick papyrus swamp with a few floating papyrus islands. The southern and northern sections were once separated by a mass of firmly rooted papyrus (Okemwa 1981). These papyrus have been uprooted and now they exist as papyrus islands; therefore, currently there is free movement of water between the two sections of the lake. The major plankton groups in the lake are blue-green algae and a few green algae; the zooplankton community is represented by copepods (*Thermocyclops* spp.), a few cladocerans and rotifers (*Brachionus* spp.) (Mavuti 1989). However, the plankton community is poorer than that of Lake Victoria, probably due to progressive salinisation. Besides the swamp vegetation, other aquatic macrophytes present in the lake include *Commelina africana*, *Ludwigia leptocarpa* and *Phragmites* sp. These macrophytes harbour a rich community of other plants and animals (Opiyo 1991).

Threats

Lake Kanyaboli is currently facing a number of threats. Water hyacinth perches have been noticed within the Yala Swamp and may find their way into this lake (Species Survival Programme – SSP 1994). Fishing activities in the lake are not controlled, hence overfishing and wrong gillnet mesh sizes are in use. About 50 fishermen operate in the lake, most of whom are not licensed.

Lake Sare

This lake forms part of the outlet of Yala River into Lake Victoria. The lake is about 5 km^2 in area and 5 m deep at its centre. It lies at an altitude of 1140 m a.s.l. It used to be a gulf of Lake Victoria, but since their separation it is no longer influenced by the waters of the main lake. Like Kanyaboli, Lake Sare is also surrounded by papyrus swamp which merges with the main Yala Swamp. The water chemistry of this lake is therefore similar to that of the surrounding swamp (Table 2).

The physico-chemical characteristics of this lake are influenced by the flow of the Yala River. Before reaching Lake Sare, the water passes through the filtering systems of the swamp and therefore contains very little nutrients and suspended matter (Mavuti 1989).

Fish species composition

The fish fauna of Lake Sare is not as rich as that of Kanyaboli. However, the lake has a diverse population of haplochromines compared to that of Kanyaboli. There are between 9 and 10 haplochromine species in this lake (Kaufman 1989). No reports are available on the taxonomy of these haplochromines. Also present are the tilapias *Oreochromis niloticus* and *O. leucostictus*. In the fringing swamp around the lake there are a few *Protopterus aethiopicus*, *Synodontis victoriae*, *S. afrofischeri*, *Clarias gariepinus*, *Xenoclarias* sp. and *Barbus* sp. The voracious predator *Lates niloticus* is present in this lake and co-exists with the haplochromines. Another notable feature of the lake is the absence of *Oreochromis esculentus* and *O. variabilis*, which occur abundantly in Lake Kanyaboli. It is possible that these have been eliminated due to predation pressure by the Nile perch. The lake is fished with a wide variety of methods, which include:

1. 'Wira' – These are enclosures made of *phragmites* stems constructed around lagoons and the mouth of Lake Sare to Victoria.
2. Beach seines – used in the middle of the lake as purse seines. They are the main gears used during the dry season.
3. Long lines – are also used mainly in the middle of the lake.
4. Gillnets – are used near papyrus and in the middle of the lake.

Flora and other fauna

The benthic fauna of Lake Sare consists of burrowing nematodes, chironomids, *Chaoborus* sp., and swamp oligochaetes (*Alma emini* and *Limnodrilus* sp). Limnologically, the lake is very unproductive. The water column contains very little phytoplankton and zooplankton; a few specimens of *Aulacoseira* sp., *Microcystis* sp., *Navicula* sp. and cyclopoid copepods are found in very low densities (less than 2 individuals l^{-1}), compared with Lake Victoria plankton densities (380 individuals l^{-1}; Mavuti 1989; Opiyo 1991).

Threats

The fishery of Lake Sare depends largely on seasonal rain, which results in the ascent of migrant fish from Lake Victoria. Perhaps the other threat to this small lake is overfishing, especially of the haplochromine species which have not been identified. Some of these species may disappear before they are named and studied.

Lake Namboyo

This is a small lake of about 0.01 km^2 but has a depth of between 15 and 20 m. It is surrounded by rooted as well as floating papyrus swamps, mainly *Papyrus latifolia*. There is very little mixing between Lake Namboyo and the main swamp, hence the lake has dilute waters compared with the other two lakes (Table 2).

Table 3. Summary of the ichthyofauna of the three lakes.

Water body	Fish species
Lake Kanyaboli	*O. niloticus, O. leucostictus, O. variabilis, O. esculentus* *Haplochromis* spp. (5–6) *Clarias gariepinus, Aplocheilichthyes pumilis, Protopterus aethiopicus, Xenoclarias* sp., *Schilbe* sp.
Lake Sare	*Haplochromis* spp. (9–10) *Oreochromis niloticus, O. leucostictus, Protopterus aethiopicus, Synodontis victoriae, S. afrofischeri, Barbus* sp., *Clarias gariepinus, Lates niloticus*
Lake Namboyo	*Oreochromis esculentus, O. leucostictus, Haplochromis* spp., *Clarias gariepinus*

Sources: Okemwa (1981), Mavuti (1989), Opiyo (1991), Species Survival Programme – SSP (1994), Aloo (2000).

Fish species composition

Very little work has been carried out in this lake compared to the other two lakes, hence not much is known about the fish fauna of the lake. Fishermen state that there are unknown numbers of haplochromine species which have not been identified. The tilapias *Oreochromis esculentus*, *O. niloticus* and *O. leucostictus* are also present in the lake but occur in low numbers, while *Clarias gariepinus* also occurs in the lake (Species Survival Programme – SSP 1994).

Threats

Since very little is known about Lake Namboyo, there are no reports of threats to its biodiversity.

Discussion and recommendations

Reclamation of part of the Yala Swamp without an early survey of the ichthyofauna of the Lakes Kanyaboli, Sare and Namboyo is a classical example of the physical alteration of tropical habitats which has led to the disappearance of many species before they are even named or understood (Table 3). An evaluation of the biological diversity of these lakes by scientists, environmentalists and policy makers was necessary before reclamation. It is unfortunate that the flora and fauna of the three lakes were never studied before the reclamation of a portion of the Yala Swamp (Okemwa 1981).

Any measures which alter the flood plain during the floods can affect the fishery of aquatic systems (Welcomme 1972). The Yala swamp has been reclaimed partially and dykes have been constructed, thereby destroying the permanent swamp, turning it into cultivated land. This reduced the available habitats for fish and other flora and fauna closely associated with the swamp. The absence of anadromous fishes from Lake Kanyaboli is a testimony to the fact that the fisheries of these lakes have been interfered with (Okemwa 1981; Opiyo 1991).

Wetlands like the Yala Swamp should be restored and rehabilitated whenever possible in accordance with the RAMSAR Convention of 1975. Progressive encroachment on, and loss of such wetlands constitute serious, and sometimes irrepairable, environmental damage that must be avoided. The swamp contains many plants and animals whose values are not known but they make the lives of the surrounding community better every day. Unfortunately a recent report indicated that the government of Kenya has put aside Kshs 200 million to drain the swamp for agricultural purposes (Anonymous 2001).

The co-existence of the Nile perch with haplochromines in Lake Sare is not unique to this ecosystem. In the sublittoral waters of the main Lake Victoria, the haplochromines have survived, recovered, invaded or co-existed with the Nile perch (Witte et al. 2000). Reports from Lake Nabugabo in Uganda indicate that the Nile perch was introduced into the lake during 1960–1963 but most haplochromines have survived in the wetland ecotones during 1993–1994 (Chapman et al. 1996).

Although water hyacinth has caused many problems in Lake Victoria and hence should be prevented from spreading into the satellite lakes, several positive aspects of the weed have also been noticed. The invasion and spread of the hyacinth in Lake Kyoga coincided with an increase in biodiversity, i.e., the recovery of haplochromine cichlids that had declined after the Nile perch introduction (Ogutu-Ohwayo 1995). Willoughby et al. (1993), cited in Ogutu-Ohwayo (1995), have observed that the hyacinth can support a large and diverse community. Several authors have pointed to the use of water hyacinth mats as refugia by haplochromines (Chapman et al. 1996). Since most haplochromines are not as sensitive to low oxygen concentrations as Nile perch, they can escape predation under the hyacinth mats. This has, in turn, led to a strong increase of little egrets in Lake Victoria. These birds stroll the mats and catch the fish hiding underneath (Wanink 2000). In areas covered with water hyacinth the recovery of *Clarias gariepinus* and *Protopterus aethiopicus* was observed (Bugenyi and Van der Knaap 1998), while Ogari (2000) added *Momyrus* spp. to the list of species that have increased after hyacinth invasion. Njiru et al. (2000) attributed the increase in the first two species to, among other factors, the provision of breeding and feeding places by the weed.

Lakes Kanyaboli, Sare and Namboyo are not the only satellite lakes within the Lake Victoria basin. Other lakes occurring within the basin include Nabugabo (Chapman et al. 1996), Nawampasa (Kaufman et al. 1997) and some 27 satellite lakes in Tanzania (Katunzi 2000). On the Kenya side of the lake it is believed that there are more satellite lakes which are yet to be reported (Species Survival Programme – SSP 1994).

The three satellite lakes have a unique fish fauna and can only be compared to the species composition of Lake Victoria in the 1950s. This rich biological diversity should be conserved at all cost for future generations. The following proposals should be considered as urgent measures towards conserving the swamp and the three lakes.

1. A survey should be carried out in the swamp to establish the total number of satellite lakes within the swamp, since reports have indicated the presence of more than these three lakes.

2. A thorough study of the ichthyofaunal composition of these lakes should be carried out to establish the fish species that inhabit each lake and their abundance. This should be followed by a study of their ecology (e.g. distribution, reproductive biology, feeding ecology and habitat preference). Such studies might help scientists to explain what could have happened in Lake Victoria that led to the disappearance of the endemic species. Other flora and fauna associated with the three lakes should also be investigated in detail to give a complete picture of the biodiversity of these lakes.
3. The Fisheries Department should license a limited number of fishermen in each of these lakes and take stern measures on any unlicensed fishermen thereafter. The department needs to go further and station their personnel at each of these lakes to collect statistics of the landed fish for the purposes of management. Landing beaches should also be established at each lake. Currently some of the lakes have no official landing beaches and fishing is a 'free for all' activity.
4. In view of the fact that the beach seine and small gillnet meshes are in common use in Lakes Kanyaboli and Sare, a regulation from the Fisheries Department enforcing use of gillnets of 4 in. minimum mesh and a complete ban on the use of beach seine and traps is urgently required. This will not only enable the fishermen to remove good-sized and mature fish from the fishery, but would put pressure off the young stock, enabling them to reach fishable sizes.
5. The Nile perch, *Lates niloticus* has been reported in Lake Sare and is believed to be co-existing with the haplochromines. The feeding ecology of this carnivorous fish in Lake Sare should be studied to compare with its feeding behaviour in Lake Victoria. However, measures should be taken to avoid the spread of this fish to Lakes Kanyaboli and Namboyo.
6. Control measures should be taken to avoid the spread of water hyacinth into the three satellite lakes, since it is an exotic plant and may have devastating effects in these small lakes.
7. Agricultural farms extracting waters from these lakes should not be allowed, as this will affect the levels of water with its adverse effects on the entire ecosystem, especially the fish fauna. Neither should there be use of any fertilizers which may end up in these lakes, leading to eutrophication with its known effects on aquatic systems.
8. Finally the conservation of these lakes will depend very much on the efforts made by the local people to do so. Therefore these people need to be sensitised on the importance of these lakes, not only to them as a source of their livelihood but also for conservation of biological diversity. Moreover, any conservation measures should take into account the socio-economic activities of these people and involve them in the conservation process.

Conclusions

The three satellite lakes are reservoirs for some endemic fish species that disappeared from Lake Victoria, especially the tilapiines and the haplochromines.

Therefore, the biodiversity of these lakes should be conserved at all costs. The Yala Swamp and the lakes should be declared as national parks or reserves. Destruction of the Yala Swamp will obviously disrupt the natural cycles and services offered by this wetland, which should not be taken for granted.

There is much to be gained from conserving the biodiversity of the Yala Swamp lakes and the satellite lakes. The local communities depend on plant and animal species from the swamp for food, medicines and raw materials. The genetic resources contained within such aquatic environments form the basis of continued existence of mankind, and the beauty and varieties of the species greatly improve their quality of life. However, we cannot continue to exploit our biological diversity indefinitely. Conservation of biological diversity is a slow process, but some action must be taken now. National and international measures must be put in place to protect both plants and animals found within the Yala Swamp lakes.

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References

Aloo P.A. 1999. A survey of the Yala Swamp lakes. Unpublished report, Kenyatta University.

Aloo P.A. 2000. Ecological values of the Yala Swamp lakes in the Lake Victoria basin, Kenya Paper presented at an International Conference on ‘Lake Victoria 2000: A New Beginning’. Jinja, Uganda.

Anonymous 1993. World Population Prospects, The 1992 Revision. United Nations, New York.

Anonymous 2001. Kenya Government to spend 200 m on Yala Swamp. Government of Kenya, Nairobi.

Balirwa J.S. 1995. The Lake Victoria environment: its fisheries and wetlands – a review. Wetlands Ecology and Management 3: 209–224.

Bugenyi F.W.B. 1987. Human activities and the detrimental aspects inflicted on the Nile and its resources in Uganda. Unpublished report, Uganda Freshwater Fisheries Research Organization.

Bugenyi F.W.B. and Van der Knaap M. 1998. Lake Victoria: an example of ACP-EU Fisheries Research. EC Fisheries Cooperative Bulletin 10: 20–21.

Cadwalladr D.A. 1965. The decline in the *Labeo Victorianus* Boulenger (Pisces: Cyprinidae) fishery of Lake Victoria and an associated deterioration in some indigenous fishing methods in the Nzoia River, Kenya. East African Agricultural and Forestry Journal 30: 249–256.

Chapman L.J., Chapman C.A., Ogutu-Ohwayo R., Chandler M., Kaufman L. and Keiter A.E. 1996. Refugia for endangered fishes from an introduced predator in Lake Nabugabo, Uganda. Conservation Biology 10: 554–561.

EAFFRO 1964. East Africa Freshwater Fisheries Research Organisation. Annual Report 1964.

FAO 1994. Fisheries characteristics of the shared lakes of the East African Rift. FAO, Rome.

FAO/UNDP 1965. Report on Yala Swamp Reclamation Project.

Garrod D.J. 1961. The rational exploitation of the *Tilapia esculenta* stocks of the northern Buruma island areas of Lake Victoria. East African Agricultural Forestry Journal 27: 69–76.

Gray J.S. 1997. Marine biodiversity: patterns, threat and conservation needs. Biodiversity and Conservation 6: 153–175.

Harley K.L.S. 1990. The role of biological control in the management of water hyacinth (*Eichhornia crassipes*). Biocontrol News and Information 11: 11–22.

Harper D.M. and Mavuti K.M. 1996. Freshwater wetlands. In: McClanahan T.R. and Young T.P. (eds), East African Ecosystems and Their Conservation. Oxford University Press, Oxford, UK, pp. 217–239.

Hecky R.E. and Bugenyi F.W.B. 1992. Hydrology and Chemistry of the African Great Lakes and water quality issues: problems and solutions. Mitteilungen Internationale Vereinigung für Theoretische und Angewandte Limnologie 23: 45–54.

Heywood V.H. and Watson R.T. (eds) 1995. Global Biodiversity Assessment. Cambridge University Press, Cambridge, UK, 1140 pp.

Katunzi E.F.B. 2000. Satellite lakes, rivers and dams as relics of Lake Victoria. In: Book of Abstracts, Lake Victoria 2000: A New Beginning (International Conference). LVFO, Jinja, Uganda p. 56.

Kaufman L.S. 1989. Challenges of fish faunal conservation programmes as illustrated by captive biology of Lake Victoria cichlids. Fifth World Congress on Breeding Endangered Species in Captivity., pp. 10–20.

Kaufman L.S. and Ochumba P. 1993. Evolutionary and conservation biology of cichlid fishes as revealed by faunal remnants in Northern Lake Victoria. Conservation Biology 7: 719–730.

Kaufman L.S., Chapman L.J. and Chapman C.A. 1997. Evolution in fast forward: Haplochromine fishes of the Lake Victoria region. Endeavour 21: 23–30.

Kudhongania A.W., Twongo T. and Ogutu Ohwayo R. 1992. Impact of the Nile Perch on the fisheries of Lakes Victoria and Kyoga. Hydrobiologia 232: 1–10.

Kudhongania A.W., Ocenodongo D.L. and Okaronon J.O. 1996. Anthropogenic perturbations on the Lake Victoria Ecosystems. In: Johnson T.C. and Odada E.O. (eds), The Limnology, Climatology and Paleoclimatology of the East African Lakes. Gordon and Breach Publishers, Melbourne, Australia.

Ligtvoet W., Mous P.J., Mkumbo O.C., Budeba Y.L., Goudswaard P.C., Wanink J.H. et al. 1995. The Lake Victoria fish stocks and fisheries. In: Witte F. and Van Densen W.L.T. (eds), Research on Lake Victoria Fish Stocks and Fisheries: A Handbook for Field Observations. Samara Publishing Ltd., Cardigan, UK, pp. 11–53.

Mavuti K.M. 1989. An account of some important freshwater wetlands of Kenya. In: Crafter S.A., Njuguna S.G. and Howard G.W. (eds), IUCN Conference Proceedings on Wetlands of Kenya., pp. 23–35.

Muggidde R. 1992. Changes in phytoplankton primary productivity and biomass in Lake Victoria (Uganda), M.Sc. Thesis, University of Manitoba.

Mkumbo O.C. and Ligtvoet W. 1992. Changes in the diet of the Nile perch *Lates niloticus* (L.), in the Mwanza Gulf of Lake Victoria. Hydrobiologia 232: 1–10.

Njiru M., Othina A., Tweddle D. and Cowx I.G. 2000. Lake Victoria invasion by water hyacinth: a blessing for Lake Victoria Fisheries. In: Book of Abstracts, Lake Victoria 2000: A New Beginning (International Conference). LVFO, Jinja, Uganda, pp. 80–81.

Ogari J. 2000. Impact of exotic fish species and invasive water weeds such as the water hyacinth on Lake Victoria Fisheries. In: Book of Abstracts, Lake Victoria 2000: A New Beginning (International Conference). LVFO, Jinja, Uganda, pp. 36–37.

Ogutu-Ohwayo R. 1990. The decline of the native fishes of Lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile Perch, *Lates niloticus* and the Nile tilapia, *Oreochromis niloticus*. Environmental Biology of Fishes 27: 81–96.

Ogutu-Ohwayo R. 1995. Diversity and stability of fish stocks in Lakes Victoria, Kyoga and Nabugabo after establishment of introduced species. In: Pitcher T.J. and Hart P.J.B. (eds), The Impact of Species Changes in African Lakes. Chapman & Hall, London, pp. 59–81.

Okemwa E.N. 1981. A Preliminary Survey of the Fisheries and Limnology of Lake Kanyaboli and Lake Sare in Western Kenya. Proceedings of the Workshop of the Kenya Marine and Fisheries Research on 'Aquatic Resources of Kenya'., pp. 192–211.

Opiyo S.V. 1991. Feeding ecology of *Oreochromis esculentus* (Graham) (Pisces: Cichlidae) in Lake Kanyaboli, Kenya, M.Sc. Thesis, University of Nairobi, 147 pp.

Pitcher T.J. and Hart P.J.B. 1995. The Impact of Species Changes in African Lakes. Chapman & Hall, London.

Rabuor C.O. and Polovina J.J. 1995. An analysis of the multigear, multispecies fishery of the Kenyan waters of Lake Victoria. Naga, ICLARM Q 18: 34–37.

Reynolds J.E., Greboval D.F. and Mannini P. 1995. Thirty years on: the development of the Nile perch fishery in Lake Victoria. In: Pitcher T.J. and Hart P.J.B. (eds), The Impact of Species Changes in African Lakes. Chapman & Hall, London, pp. 124–181.

SeeHausen O. 1996. Lake Victoria Rock Cichlids: Taxonomy, Ecology and Distribution. Verduyn Cichlids, Berlin, Germany.

Species Survival Programme – SSP 1994. A survey of the Yala Swamp lakes and surrounding dams for endemic fish species (Unpublished report).

Twongo T., Bugenyi F.W.B. and Wanda F. 1992. The potential for further proliferation of water hyacinth in Lakes Victoria and Kyoga and some urgent aspects for research. Proceedings of the CIFA sub-committee for Lake Victoria meeting, February 1992,. Jinja, Uganda.

UNEP 1991. Environmental Data Report. 3rd edn. Basil Blackwell Scientific Publication, Oxford, UK.

Wanink J.H. 2000. Foreign relations. Swara 22: 38–41.

Welcomme R.L. 1964. The habitats and habitat preferences of the young of the Lake Victoria Tilapia (Pisces, cichlidae). Revue de Zoologie et de Botanique Africaines 70: 1–28.

Welcomme R.L. 1972. A brief on the flood plain fishery of Africa. African Journal of Tropical Hydrobiology and Fisheries 1: 67–76.

Welcomme R.L. 1988. International Introductions of Inland Aquatic Species. FAO Fish Technology Paper 249. FAO, Rome.

Willoughby N.G., Watson I.G., Lauer S. and Grant I.E. 1993. An investigation into the effects of water hyacinth on the biodiversity and abundance of fish and invertebrates in Lake Victoria, Uganda. Technical Report. Natural Resources Institute, Overseas Development Administration, UK.

Witte F., Msuku B., Wanink J.H., Seehausen O., Katunzi E.F.B., Goudswaard P.C. et al. 2000. Recovery of cichlid species in Lake Victoria: An examination of factors leading to differential extinction. Reviews in Fish Biology and Fisheries 10: 233–241.