Efforts to incorporate Biodiversity Concerns in Management of the Fisheries of Lake Victoria, East Africa

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Abstract

Up to the 1980s, Lake Victoria in East Africa had very high diversity of fish and other aquatic organisms and a varied ecosystem. Diversity of the biotic communities declined and the ecosystem deteriorated due to excessive fishing pressure, alien fish stockings and ecosystem changes related to poor watershed management. This affected the diversity of the ecosystem, the species and the gene pool. Various efforts have been initiated to conserve and enhance species and genetic diversity by: controlling fishing effort; identifying and protecting endangered species and habitats; mapping and setting up conservation areas; controlling pollution and eutrophication of the fish habitat; and improving information dissemination, policy and institutional framework.

Relationships between Components of Aquatic Systems

Fisheries management has historically concentrated on management of commercially important fisheries without considering other components of the ecosystem. This approach has resulted in loss of species and destruction of the fish habitat. Sustainable use of aquatic resources requires adequate understanding and management of the different components of the ecosystem which includes fish, plants and animal life which support fish production plus their physico-chemical environment. For instance, primary production processes are determined by nutrients and other physico-chemical conditions. Variability in nutrient levels and in physico-chemical parameters will affect production processes. The diversity of organisms in an ecosystem is also affected by trophic diversity. Some organisms are specialized to feed at certain trophic levels and on specific organisms. Changes in the type of food, especially for highly specialized organisms will affect the abundance of such organisms. Management of aquatic resources should therefore, include management of the different components that support and determine production processes. The importance of this relationship can be appreciated by invoking the trophic cascade theory, which stipulates that changes in the composition and abundance of organisms at one trophic level will alter the composition and abundance of organisms at other trophic levels (Carpenter *et al* 1985). Changes in the trophic structure of Lake Victoria in comparison to satellite water bodies in the same catchment illustrate the importance of ecosystem management for biodiversity and fisheries. This paper discusses the historical trends in the fishery of Lake Victoria and the efforts that are being made to incorporate biodiversity and other ecosystem factors in the management of the lake fisheries.

Geographic Setting of Lake Victoria

Lake Victoria is the second largest freshwater body in the world and the largest tropical lake. It is located in East Africa. It has a surface area of 68,800 km^2, a shoreline length of 3450 km^2 catchment area of 193,000 km^2, a mean depth of 40m and a maximum depth of 80m. The lake is shared between three sovereign states (Kenya, Uganda and Tanzania) but its watershed extends to two other states (Rwanda and Burundi). Tanzania has the largest portion of the water surface (51%), followed by Uganda (43%) and Kenya (6%). The main rivers feeding Lake Victoria include Rivers Nzoia, Yala and Sondu-Miriu from Kenya; River Mara from Tanzania, River Kagera from Rwanda and Burundi and River Katonga from Uganda. The outflow is via the Victoria Nile in Uganda. Downstream, Lake Victoria is connected to Lake Kyoga by the upper Victoria Nile. The two lakes have a number of satellite lakes within their basins with which they share similar biotic communities.

Importance of Fisheries and Biodiversity in Fisheries

Lake Victoria has been a major source of fish, the most affordable high quality protein for the people around it. The lake provides water for domestic and industrial use, is used for waste disposal, is an avenue for transport, and moderates regional climate. Lake Victoria and two other African Great lakes (Malawi and Tanganyika) had very high fish species diversity. These three African Great Lakes are among the richest centres of aquatic biodiversity especially fish. These lakes also lie in one of the poorest regions of the world and fish from the lakes is a basis of employment, food and income. These lakes represent a spectacular example of rapid speciation, best demonstrated by the haplochromines. For example, there were over 500 species of haplochromines in Lake Victoria alone, more than 99% of which were endemic (Kaufman 1997, Seahausen 1996; Witte *et al* 1992a, b) and these fishes comprised over 80% of the fish stocks in Lake Victoria (Kudhongania & Cordone, 1974). Lake Kyoga and the satellite lakes in the Victoria and Kyoga lake basins are the only other water systems in which some of the Victorian fauna were found (Worthington, 1929).

Most of the fishery yield from Kenya, Uganda and Tanzania is from Lake Victoria. The lake is, therefore important to the economies of these countries. In Uganda, the fishing industry employs between 0.5 to one million people. Fish is currently among the most important export commodities in Uganda and in 1996, it was second only to coffee (the most important export commodity) in export earnings. However, some of the fish fauna of Lake Victoria, which have been impacted by ecological changes in the lake especially the haplochromines, were of scientific value and were valuable in ecological and evolutionary studies, and others were of medicinal value. Other components of the ecosystem such as algae and invertebrates provided food for fish and are important in sustaining a stable and productive ecosystem. Haplochromines occupied all trophic levels and played a major role in the flow of energy in the ecosystem. They were crucial in maintaining the ecosystem diversity that supported other food fishes, as well as the high biodiversity associated with the lake basin. Therefore, the observed reduction in fish diversity shows that maintenance/conservation of gene-species-ecosystem diversity has value implications beyond fish catch.

The Early Fisheries, their Exploitation and Management

Lakes Victoria and Kyoga originally had a diverse fish fauna (Graham 1929; Worthington 1929). The lakes had a multi-species fishery comprising of about 14 taxa of which two tilapiine species, (*Oreochromis esculentus* and *O. variabilis)*, were the most important. These two species are endemic to the Victoria and Kyoga Lake basins (Graham 1929; Greenwood 1965). The rivers of the Victoria and Kyoga Lake basins supported important fisheries of *Labeo victorianus* and *Barbus altianalis* (Cadwallader; 1965). Until the 1960s, the lakes also contained small sized species notably *Restrineobola argentea* and haplochromine cichlids, but these were not originally commercially exploited.

At the time of the first fishery of Lake Victoria survey, in 1927 (Graham, 1929), the lake was fished by natives around it. Overall, there was equity in access to the resources by the different people. Fishing was dominated by men while fish processing and marketing were predominantly by females. The fishing crafts were small thus restricting fishing activities to shallow inshore areas.

Status and Past Trends due to Human Exploitation and Management Efforts for Lake Victoria

The Lake Victoria fishery was originally exploited using locally made basket traps, hooks and seine nets of papyrus which were affordable by the fishermen. These fishing methods had little impact on the fish stocks. The pressure on the fisheries started to increase with the introduction of more efficient gill nets in 1905 and the expansion of the markets due to extension of the railway line from major urban centers to the lake. This resulted into an increase in fishing effort as manifested in catch rates. Initially it had been possible to catch as many as 50 to 100 *O. esculentus* per net of about 50 m long each night (Jackson 1971) but this catch rate later decreased with increasing effort. A fishery survey was conducted in 1928 (Graham 1929) to assess the status of the fish stocks and to propose management measures. This survey showed that *O. esculentus* were being over-fished and recommended that a minimum gill net mesh size restriction of 127 mm (5 inches) be imposed. This was effected in 1931. In addition, a lake-wide institution was set up to manage the fishery the Lake Victoria Fisheries Service (LVFS). This organization was charged with the responsibility of collecting statistics and enforcing the mesh size regulation. A fisheries research organization, the East African Freshwater Fisheries Organization (EAFFRO) was formed to carry out biological and ecological research to guide management options.

There was however, no limit to the fishing effort and, as a result, the catches of *O. esculentus* decreased to 1.6 fish/net/night by the 1950s. As the catch in the larger mesh size nets decreased, the fishermen shifted to smaller mesh size gill nets. The catch in the smaller mesh size gill nets were better than those in the 127 mm mesh size nets and this made the mesh size limit so difficult to enforce that it was repealed. This marked the collapse of the originally most important fishery of Lake Victoria. *O. esculentus* became one of the endangered fish species in the Victoria and Kyoga lake basins. The fishing pressure continued to increase and the catch rates decreased due largely to the open access policy and the extensive dependency of the lakeside communities on the fisheries. Fishermen shifted to smaller mesh size gill nets to catch the smaller unexploited sizes of fish whenever the catch in the larger mesh sizes decreased. As a result the 127mm mesh-size regulation was repealed in Uganda and Tanzania in 1956 and in Kenya in 1961 (Kenya Fish. Dept. Ann. Rep.1961). This was the first blow to management of the fishery of Lake Victoria. Recommendations similar to those of Graham (1929) were made by Beverton (1959), Garrod (1960, 1961a, b) and Marten (1979) but were not followed. The LVFS was also disbanded in 1960 and its role transferred to the individual national fisheries departments of Kenya, Uganda and Tanzania. There was no longer a regional mechanism to manage or coordinate management of this shared resource. Only

EAFFRO survived as a regional research institution under the East African Community. This later disintegrated in 1977 following collapse of the then East African Community and its stations emerged into independent research stations namely Fisheries Resources Research Institute (FIRRI) in Uganda, Kenya Marine and Fisheries Research Institute (KEMFRI) in Kenya and Tanzania Fisheries Research Institute (TAFIRI) in Tanzania.

The stocks of *Labeo victorianus*, which formed the most important fishery along the rivers of the Victoria and Kyoga lake basins were also depleted through intensive exploitation. *L. victorianus* live in the lake but ascend the rivers to breed during the rainy season (Cadwalladr 1965). This fishery was damaged through intensive exploitation of gravid females by setting nets at the mouths of the rivers and catching the fish at the time when they were migrating up the river to breed. Ideally, the mouths to the rivers should have been closed to fishing during the rainy season to protect breeding females. This made *L. victorianus* one of the endangered fish species in the Lake Victoria basin.

As the larger species became scarce, fishermen shifted to smaller originally less exploited haplochromines and *R. argentea*. Haplochromines were the most abundant fish in Lake Victoria in 1970s and comprised up to 80% of the demersal fish stocks (Kudhongania and Cordone 1974) and remained so up to the early 1980s (Okaronon *et al*, 1985). Bottom trawling was introduced in the Tanzania part of the lake in the early 1970s to exploit the haplochromines (Ogutu-Ohwayo, 1990a). This was followed by a rapid drop in catch rates. It seems from this and the subsequent changes in haplochromines following establishment of Nile perch that haplochromines did not have the capacity to withstand heavy exploitation. Up to this time, however, the fish were well distributed over the entire depth of the lake.

When the stocks of the originally important commercial species declined, fisheries management efforts shifted to the small sized originally less exploited species. A fish stock assessment was commissioned in 1967 to determine the magnitude of haplochromines fish stocks. Options for processing marketing them were also investigated. This survey showed that the Lake contained at least 650,000 metric tones of fish 80% of which were haplochromines (Kudhongania & Cordone 1974). These could be exploited by trawling and converted into fish meal. On this basis, trawling was started in the Tanzanian waters of Lake Victoria. It was not long before this started showing symptoms over-fishing. Catch rates of haplochromines started declining rapidly. This lack of resilience was to be demonstrated later when introduced species especially Nile perch got established in the lake.

One of the most significant events in management of the fisheries of Lake Victoria was introduction of new fish species to boost production. *L. niloticus* and four tilapiine species; *O. niloticus*, *O. leucostictus*, *T. zillii* and *T. melanopleura* were introduced into Lake Victoria in 1950s and early 1960s to improve declining stocks of large commercial species (Gee 1964, Welcomme 1964, 1966). Nile perch was introduced to feed on haplochromines and convert them into a larger fish of higher commercial value. The tilapiine species were introduced to improve stocks of native tilapiines which had declined due to over-fishing.

Stocks of the introduced species increased rapidly between 1971 and 1983. This was followed by a decline and in some cases total disappearance of some of the native species (Ogutu-Ohwayo 1990a, 1992, 1997; Witte *at al* 1992a, b). About 200 out of an estimated

300+ species of haplochromines are believed to have disappeared. Nile perch contributed much to the decline especially the haplochromines as these formed its main food in lakes Victoria and Kyoga (Gee 1969; Hamblyn 1966; Ogutu-Ohwayo 1985, 1990a, b, 1994; Okedi 1971). Haplochromines were still abundant in Lake Victoria by the time the Nile perch got established (Kudhongania and Cordone 1974; Okaronon *et al* 1985) and the decline in their stocks coincided with increase in Nile perch stocks (Ogutu-Ohwayo 1990a). Improvement in haplochromine stocks would, therefore require reduction in Nile perch stocks.

When haplochromines were abundant, there was high trophic diversity of fishes. This is thought to have contributed to overall stability of the ecosystem. The haplochromine community comprised of phytoplanktivores, zooplanktivores, insectivores, piscivores, parasite eaters, egg eaters, detritivores, epilithic and epiphytic algal grazers, plant eaters, molluscivores, and scale eaters (van Oijen 1982, Goldschmidt *et al* 1990, Witte *et al* 1992a, b). Feeding by the different trophic groups played an important role in the flow of energy in the lake.

The introduced and native tilapiines have similar feeding requirements with the introduced *O. niloticus* having a wider food spectrum than the native tilapiines. These species especially *O. niloticus*, seem to have contributed to displacement especially of native tilapiines through competition and/or hybridization. *O. niloticus* has displaced other tilapiines from waters to which it has been introduced (Siddiqui 1977; Welcomme 1984).

Trends in Non-target Biodiversity Concerns

Although there had been some efforts to manage the fisheries, there was no significant effort to manage biodiversity and the fish habitat. During the mid 1980s, major ecosystem changes started manifesting themselves on Lake Victoria. Algal blooms and mass fish kills became frequent on the lake. A comparison of data collected during 1960s with that of the 1990s showed that the concentration of phosphorus in the lake had doubled between 1960 and 1990 while that of silicon had decreased by a factor of 10 (Talling 1966, Hecky 1993, Mugidde 1993). Algal species composition had changed from dominance of diatoms (*Melosira)* to nitrogen fixing cyanobacteria some of which can produce phyto-toxins. Phytoplankton production had doubled and algal biomass increased four to five times (Mugidde 1993). This resulted in a four-fold decrease in water transparency. The diatoms which had disappeared were originally the most important food of *O. esculentus* (Graham, 1929) and this could have affected its stocks.

Changes in biotic communities also occurred among invertebrates. The composition and diversity of zooplankton community changed from dominance of larger types (calanoid copepods and cladocerans) to smaller types (cyclopoid copepods) probably due to changes in the types of their food and the abundance of organisms feeding on them (Worthington 1931, Rzoska 1956, Mwebaza-Ndawula 1994). This simplified the food-web and reduced the grazing efficiency of zooplankton (Lehman & Branstrator 1993).

The depletion of the trophically complex haplochromine community discussed earlier and the changes in zooplankton community is thought to have reduced the grazing pressure. This left much of the organic matter produced due to high algal growth in the lake unconsumed. Decomposition of this organic matter depleted the water column of oxygen and contributed to anoxia that was observed in parts of the lake deeper than 40m. This is thought to have driven haplochromines to shallower waters where they fell easy prey to Nile perch (Ogutu-Ohwayo & Hecky 1991). The expansion of the anoxic layer enabled only those organisms which can tolerate low oxygen conditions e.g. chironomid and chaoborid larvae, and C*aridina nilotica* to proliferate.

The water hyacinth, *Eihhornia crassipes*, invaded Lake Kyoga in 1988 and Lake Victoria in 1989 (Twongo 1996). Water hyacinth occupied the shallow, sheltered bays which are breeding, nursery and feeding grounds for fish. The zone below extensive water hyacinth mats was deficient in oxygen which reduced habitable space for most fish and other aerobic organisms upon which fish feed, and affected aquatic biodiversity. Among the fishes, only *Protopterus aethiopicus* which can tolerate low oxygen conditions flourished under water hyacinth mats. The invertebrate community under hyacinth was again dominated by low oxygen tolerant types, chaoborids and chironomids (Wanda 1997). Whereas hypoxia had driven the deep-water species to shallower waters, the anoxic conditions created by water hyacinth were driving them out of their shallow water refuge.

Examination of paleolimnological information (Hecky 1993) suggests that the changes in the physico-chemical conditions and lake productivity processes in Lake Victoria started at the turn of the century as human activities in the catchment areas. At that time, certain species of algae increased while others declined. These changes however, accelerated during the 1960s.

The Original Institutional, Policy and Legal Framework

The riparian countries of Lake Victoria each has a Fisheries Act. The Acts provide for development, management, exploitation, conservation, processing and marketing of fish. These Acts contained no specific reference to conservation of aquatic biodiversity. The only significant restriction related to biodiversity conservation is restriction of non-indigenous fishes including their egg. There is room for a Minister responsible for fisheries to amend the Act to match any changes.

Lessons from Past Efforts to Manage the Fisheries of Lake Victoria

The overall lesson was that management measures have normally been in response to a crisis. The collapse of the *O.esculentus* suggests that there should have been strict control over mesh size limits, while that of *L. victorianus* emphasized the need to protect critical fish habitats.

Fishermen are very innovative and tend to adjust rapidly to a changing fishery. For instance, whenever there were changes in catches the fishermen shifted to what was available. There is therefore need for measures to avoid this happening eg, by prohibiting introduction of new fishing gears and methods. Introduction of predatory species can deplete stocks of native species. Recovery of stocks of such native species will depend on removal of the introduced species by fishermen.

Introduction of a species which is genetically similar to resident species will affect the resident species. In addition, combination of species with similar ecological requirement can affect the species.

Introduction of new fish species may have both positive and negative results. There is, therefore need to consider both positive and negative impact of an introduced species when management options are being considered.

Ecosystem changes may start and take time to manifest themselves. It is therefore important to monitor changes and take measures before it is too late.

The changes in the environment and in other components of the aquatic systems suggest that sustainability of the aquatic system depends on proper management of other components of the aquatic environment.

Current Fisheries and how Biodiversity has been Incorporated into their Management

International commitment to conservation of biodiversity

The threat to global biodiversity culminated into one of the most important international agreements the Convention on Biological Diversity, (CBD), prepared in Rio de Janeiro in 1992. In ratifying the CBD, governments agree to take actions to: conserve biological diversity; ensure sustainable use of its components; and ensure fair and equitable sharing of benefits from genetic resources. The changes in biodiversity that have occurred in Lake Victoria due to human exploitation, environmental degradation and introduction of exotic are of direct application to the CBD. The riparian states of Lake Victoria are implementing measures for conservation and sustainable use are of biodiversity as stipulated in Article 6 of the CBD. Some of the key areas of intervention that are being implemented on Lake Victoria include: Biodiversity identification and monitoring (*Article 7*); *In-situ* conservation *(Article 8*); *Ex-situ* conservation; *(Article 9)*; Sustainable use *(Article 10)*; Public education *(Article 13)*; and exchange of information *(Article 17)*.

The concern about the depletion of the biodiversity of Lake Victoria, and the potential, social and economic consequences of this loss has led to a number of regional and national efforts to conserve and sustainably use aquatic resources of Lake Victoria. This process has involved:

1) Sustainable use of current fisheries;

2) *Ex-situ* conservation through captive propagation;

3) Conservation of selected ecosystems and habitats in which endangered species are surviving;

4) Conservation of species in specific habitats and ecosystems;

5) Determining the biological and ecological characteristics especially of rare and endangered species to guide conservation efforts;

6) Genetic characterization especially of endangered and related species to determine genetic difference and similarities and differences so as to guide conservation efforts;

7) Managing the impact of introduced species;

8) Managing the impact of water hyacinth infestation;

9) Controlling degradation of the aquatic environment;

10) Enhance stocks endangered species through aquaculture and promote commercial production of culture species;

11) Conserving representative samples of existing biodiversity in zoos, aquaria and museum;

12) Acquisition, packaging and dissemination of information;

13) Improving policies, laws and regulations; and

14) Improving efficiency and effectiveness of service institutions.

Management of the current fishery

The establishment of introduced fish species in Lake Victoria was followed by rapid increases in fishery yield. In the Ugandan portion of the lake, annual fish catches were about 10,000 metric tonnes in 1980 increased to 132,382 metric tonnes in 1981 due to an increase in the contribution of Nile perch. Similar increase were recorded in the Kenyan and Tanzanian part of the lake. Fish catches lake-wide increased five fold from about 85,000 metric tonnes in 1975 to a peak of 554,000 metric tonnes in 1990. This has made Lake Victoria the single most important source of freshwater fish in the world.

The increase of fish catches following establishment of Nile perch resulted in establishment of fish processing plants which fillet Nile perch mainly for export and this stimulated increases in fishing effort. In the Ugandan part of the lake, fishing effort has since increased from 3,200 canoes in 1972 before the establishment to 8,674 canoes in 1990 to 15,462 canoes by 2000. The total number of boats on the lake is now 41,000. This rapid increase in fishing effort is a major threat to the fishery. There are indications that the maximum sustainable yield (MSY) has been exceeded. There is therefore need to control further expansion of the fishery through control of fishing effort by limiting the size of gears used, licensing fishing boats and limiting the number of fish processing plants.

Efforts to conserve fishes through *Ex-situ* captive propagation

The original effort to conserve the biodiversity of threatened species of Lake Victoria was to rescue endangered cichlids and breeding them in North American Aquarium and Zoos with the hope of reintroducing them into Lake Victoria. This was a collective effort of the Lake Victoria Fish Species Survival Program which was a consortium of North American Museums in collaboration with FIRRI, KMFRI, and TAFIRI. This involved collection of fish that were considered threatened in Lake Victoria and keeping them in captivity until the populations of the Nile perch had been reduced to levels where these species could be re-introduced into the lakes (Ribbink, 1987). Under this arrangement, haplochromines and O. esculentus, were collected from Lake Victoria and associated water bodies and flown to Europe and North America.

There were a number of problems with this option. At that time, the plan was that the species maintained in captivity could be re-introduced into the lakes from which they had been collected after the Nile perch populations had been reduced. There was however, no hope of completely removing Nile perch from Lake Victoria and the other lakes (Kyoga and Nabugabo) to which the predator had been introduced. Besides, this would be economically undesirable because of the large economic benefits that had been realized from Nile perch catches in Lake Victoria. The other problem was that cichlids especially haplochromines are known to undergo rapid genetic differentiation. The species kept abroad would probably have changed by the time of re-introduction. There was also a limit to the number of species which could be protected by this approach. This method was therefore of limited value.

Conservation of the Diversity of Ecosystems

One of the mechanisms of addressing biodiversity concerns of Lake Victoria is to identify and conserve the diversity of ecosystems. The diversity and the status of ecosystem health within and between the lakes containing Victorian fish fauna have been characterized on the basis of biotic and physico-chemical parameters. This has covered the main Lake Victoria and the satellite lakes within the Victoria and Kyoga lake basins. The satellite lakes that have so far been examined include Nabugabo lakes, Koki lakes and Kyoga satellite lakes in Uganda; Lake Kanyaboli in Kenya and Lake Ikimba and Burigi in Tanzania. The areas examined within the different aquatic systems include: rocky outcrops, macrophyte and papyrus wetlands, river mouths.

Some of the lakes, especially those which have been encroached upon by human activities have been observed to manifest signs of eutrophication by having low secchi depth and high Chl-a concentration. These criteria are being used to select aquatic systems and habitats, which would be valuable for biodiversity conservation. Generally, lakes which are protected from human encroachment such as Lake Agu (among the Kyoga satellite lakes) are very valuable in biodiversity conservation and are being recommended for protection. The lakes that are showing signs of eutrophication are being recommended for rehabilitation.

Almost all the native non-cichlids which occurred in the main lakes Victoria and Kyoga before the Nile perch upsurge have been encountered in a number of the satellite lakes. The satellite lakes are at different stages of human interference with some of them little or not disturbed at all. Those with high biodiversity values have been recommended for protection.

Aquatic habitats with macrophytes, near-shore areas, rocky areas and river mouths support high diversity of aquatic flora and fauna. Overall, the diversity of fish and invertebrates decreased with distance from the shore. Protection of near-shore areas and other areas supporting high biodiversity will be valuable in conservation of aquatic biodiversity of Lake Victoria.

Nile perch cannot survive under low oxygen conditions (Fish, 1956) such as those in papyrus swamps. Some native species, which can survive under these conditions, can be protected from Nile perch predation. Papyrus swamps and fringing wetlands have been observed to provide refuge from Nile perch (Chapman *et al* 1996). They also serve as barriers to movement of Nile perch between adjacent water bodies. It has therefore been recommended that papyrus swamps and vegetation along and between affected lakes should, not be cleared to protect species in them and to stop the spread of Nile perch into those lakes. For instance, the Yala swamp which separates Lake Kanyaboli from Lake Victoria has been recommended for protection to prevent the spread of Nile perch into Lake Kanyaboli. Similarly, the swamps separating lakes Manywa and Kayugi from Lake Nabugabo, and Lake Kayanja from Lake Victoria and those separating the Kyoga satellite lakes from the main lake have been recommended for protection.

Studies made elsewhere show that rocky areas are important refugia for fish and other aquatic organisms. In Lake Tanganyika, where there are *Lates* spp, most haplochromines are confined to rocky areas where they are able to evade predation by *Lates* species (Fryer & Iles 1972). In Lake Victoria, rock-dwelling species have been least affected by Nile perch predation (Ogutu-Ohwayo 1990b, Seehausen 1999, Witte *et al* 1992a, b). Rocky areas are, therefore important refugia for haplochromines and other endangered species.

Protection of refugia is foreseen as one of the most effective methods for conserving fish species diversity.

Conservation of species diversity

Information had been collected on species diversity of fish, lower vertebrates, higher vertebrates, macrophytes, algae, micro and macro invertebrates in Lake Victoria and the satellite lakes. This includes composition, abundance, distribution and size structure. The diversity of these organisms varied between the ecosystems examined. Again, less disturbed lakes have been observed to have higher species diversity compared to more disturbed ones.

Biological and ecological information of key endangered taxa notably, the native tilapiines, (*Oreochromis esculentus* & *O. variabilis*), *L. victorianus* and *Bagrus docmak* and haplochromines has been collected. The trophic ecology especially of haplochromines has also been examined. Some of these have been observed to vary considerably between lakes. For instance the relative importance, and biological characteristics of *O. esculentus* has been observed to vary between the lakes examined (Table 1). These differences have been used to determine and to recommend stocks of *O. esculentus* which should be protected.

Many of the trophic groups of haplochromines that disappeared from lakes Victoria, Kyoga and Nabugabo have been observed to survive in Kyoga satellite lakes. These lakes would be very important in conservation and understanding of the trophic diversity especially of haplochromines that existed in lakes Victoria and Kyoga some of which disappeared before they were adequately studied.

Conservation of genetic diversity

The genetic variability of haplochromines, native tilapiines, introduced tilapiines and *L. victorianus* have been examined to guide conservation efforts. The populations of *L. victorianus* showed marked genetic differences by location. There are also clear differences among populations of native tilapiines compared to introduced tilapias. Nile tilapia is least differentiated while *O. esculentus* exhibited the highest level of population sub-division. These observations suggest that conserving genetic diversity of *L. victorianus* and *O. esculentus* will require protecting many and not just single populations.

The genetic status of *O. niloticus* which has displaced the native tilapiines in lakes to which it has been introduced was evaluated. *O. niloticus* hybridizes with the two native tilapiines. *O. niloticus,* is ecologically versatile and genetically superior to the other tilapiines of the Victoria and Kyoga lake basins. This makes *O. niloticus* a threat to continued existence of the native tilapiine species. Conservation of the gene pool of the native tilapiines will depend upon ensuring complete separation of remnants of the native tilapiine population from *O. niloticus*. Some of the satellite lakes within the Victoria and Kyoga Lake basins contain the only population of native tilapiines which have not been contaminated by *O. niloticus*. It has been recommended that measures should be undertaken to safeguard against entry *O. niloticus* into these lakes.

Managing the impact of exotic Nile perch

A number of studies have been carried out to determine the impact of predation by Nile perch on other fishes. These studies showed that Nile perch had contributed greatly to reduction in stocks of fishes especially haplochromines in Lake Victoria. Recovery or improvement in stocks of endangered species would depend upon reduction in Nile perch stocks. Data collected from Lake Kyoga (Ogutu-Ohwayo 1994) shows that stocks of haplochromines had increased since 1988. This coincided with decline in Nile perch stocks and expansion of vegetation cover due to the spread of water hyacinth. This suggested that reduction in Nile perch stocks and increase in cover would allow stocks of haplochromines and other fishes to recover. Selective exploitation of Nile perch especially at the time when it feeds heavily on other fishes could reduce predation pressure on those fishes and help improving their stocks. This is however not foreseen as an appropriate option for protecting endangered species due to the high economic value of Nile perch.

Control of water hyacinth

Biodiversity has also been affected by water hyacinth infestation and from efforts to control of water hyacinth. It has been observed that the zone under large expanses of water hyacinth are devoid of oxygen and are therefore poor in biodiversity. However, narrow, adequately oxygenated water hyacinth fringes supports high biodiversity apparent through acting as refugia. Measures have been taken to control water hyacinth on Lake Victoria. This involved biological control using two weevil types *Neochetina bruchi* and *N.*

eichhornia mechanical and manual removal at strategic areas such as the hydro-power station at Jinja, the Wagon Ferry Terminal at Portbell, water extraction points and fish landings. Water hyacinth mats have also been displaced through ecological succession by native plants especially hippo grass, *Vossia cuspidata*. It has been observed that proliferation of water hyacinth is related to nutrient levels. Control of nutrient inputs to Lake Victoria is expected to contribute to control of water hyacinth.

Conservation and stock enhancement through aquaculture

One of the options being developed to avail some of the threatened food fishes has been to introduce them into fish farming. Technologies are being developed to introduce *O. esculentus* and *L. victorianus* in aquaculture.

Conserving endangered species in zoos, aquaria and museum

Some of the aquatic flora and fauna will be lost irrespective of any degree of protection. Representative samples of existing biodiversity are therefore being kept as preserved specimens in museum and other are being maintained as live specimens in aquaria and zoos at research and selected educational institutions.

Improving acquisition, packaging and dissemination of information

Creating an informed society has been recognized as a prerequisite to conservation efforts. Information is being made available to stakeholders at different levels. This is involving production and distribution of books, booklets, charts, facts sheets, brochures, geo-referenced maps to be used in biodiversity conservation efforts. Information dissemination activities are also being carried out through workshops aimed at increasing awareness of extension agents, communities, students in primary, secondary and tertiary educational institutions.

Improving policies, laws and regulation

The success of the above interventions will depend on availability of appropriate policies, laws and regulation to guide biodiversity management. The three riparian countries sharing Lake Victoria have policies laws and regulations that can be adopted to guide management of fisheries and biodiversity. The fisheries laws and regulations of the three countries are also being reviewed and harmonized in relation to management of the fisheries of Lake Victoria.

They riparian countries of Lake Victoria are also signatories to a number of regional and international agreements, conventions and protocols which include biodiversity conservation.

The regional agreements relevant to management of fisheries and biodiversity include: Technical Co-operation for the Promotion of the Development and Environmental Protection of the Nile Basin (*Tecconile*); the Convention for the Establishment of Lake Victoria Fisheries Organization (LVFO); and the Treaty establishing the East African Community (EAC). The International conventions include: the Ramsar Convention on Wetlands of International Importance; the Convention for International Trade in Endangered Species of

Wild Fauna and Flora (CITES); the Convention on Conservation of Biological Diversity; and the Code of Conduct for Responsible Fisheries.

One of the wetlands in the Victoria lake basin (the Nabugabo wetlands) are being developed into a Ramsar site whose role will include conservation of some of the fish species lost from Lake Victoria such as *O. esculentus*.

The three East African countries each have fisheries policies whose overall goal is to ensure optimal and sustainable fishery production. Objectives of the fisheries sub-sector include: increasing the sustainable fish production, conservation of aquatic biodiversity, and protection of the aquatic environment.

Each of the riparian countries has an Act specifically for management of the fisheries resources. There are a number of other Acts which apply to management of other aspects related to fisheries. The existing Fisheries Acts of Kenya, Uganda and Tanzania provide for conservation of biodiversity and specifically prohibit introduction of exotic organisms.

There are also a number of laws within the East African countries that take care of fisheries and biodiversity concerns which are not be covered in the Fisheries Acts. These cover management of the environment, water quality and wetlands.

The three East African countries are implementing National Environmental Action Plans (NEAP) which provides a framework for integrating environmental concerns in project design and implementation.

The countries around Lake Victoria already have policies and plans for management of wetlands. Uganda has a national policy for conservation and management of wetland resources in 1995. The policy provides for development of the capacity for conservation and management of wetlands up to the district level.

Some of the East African countries have specific water policies and laws for protection of water quality. The Uganda government has a water policy and a Water Statute, 1995. The water statute provides guidelines for use, protection and management of water resources and has an institutional framework for management of water resources.

The more recent laws and regulation have started incorporating biodiversity concerns. For instance, Uganda Wildlife Statute, 1966, conservation of wildlife so that to maintain the abundance and diversity of species at optimum levels and protection of rare, endangered and endemic species. In the recent past the East African governments have started developing policies that include biodiversity conservation. The three countries are implementing National Environmental Action Plan (NEAP) which require incorporating conservation of resources in development plans. There is however still inadequate coordination among sectors involved in aquatic resources management. There is need for a multi-sectoral policy reform to facilitate integration of biodiversity concerns.

Improving the efficiency and effectiveness of service institutions

The riparian countries have national and regional institutions which coordinate fisheries and related matters. The regional level is spearheaded by LVFO which is responsible for harmonization of national fisheries management efforts into regional efforts. Each riparian country has a Department or Directorate of Fisheries Resources (DoF) and the Fisheries Research Institutions (FRI); other agencies include water resources, environment, wetlands and land use management. The DoF and other related institutions spearhead the development of national policies and plans. These are then passed up to the regional level for harmonization and to the district/local government and community level for implementation. The FRI generate and disseminate information to guide management of the fisheries, biodiversity and the environment. These are discussed at the community level, passed to the national policy level and harmonized at the regional level and finally passed down for adoption and implementation. The grass-root institution responsible for management of fisheries and biodiversity include beach management units.

Lessons Learned from the Current Efforts

There is need to have adequate information to guide management options. There is need to involve communities in management efforts.

Biodiversity conservation involves many institutions. There is need to have these institutions adequately linked and for the different institutions to open up to ensure adequate dialogue.

Conclusions

Considerable progress has been made in incorporating biodiversity concerns in management of the fisheries of Lake Victoria and associated water bodies. There is also considerable amount of information to guide management of biodiversity. The legal and institutional mechanisms seems are, however still very weak and need strengthening. These efforts are in their infancy and need to be strengthened. Some of the areas needing attention include: having clear national and regional policies on biodiversity conservation and management; strengthening co-ordination of institutions dealing with aquatic resources management and biodiversity conservation; ensuring that there is adequate data to guide formulation of policies, laws and regulations; ensuring that there is adequate community participation and commitment to biodiversity conservation; and ensuring that the funds are allocated to biodiversity conservation efforts.

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Figures and Tables

Table 1. Population characteristics of *O. esculentus* in different lakes of the Victoria and Kyoga Lake basins. [1]

Parameter	Lake					
	Kayanja	Kayugi	Mburo	Kachera	Kawi	Lemwa
Contribution to fish catch % by number	23.3	6.7	33.5	20.4	3.4	1.5
Maximum size (cm)	28.0	38.7	26.0	28.5	25.0	17.0
Size at 50% maturity (females)	15.4	20.5	16.8	17.0	15.6	17.0
Condition factor	1.5	1.9	1.8	1.9	2.0	1.8
Females per male	0.9	1.0	1.5	0.8	0.5	0.7

[1] Source: Based on data in Nagayi 1999.