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Challenges for Management of the Fisheries Resources, Biodiversity and Environment of Lake Victoria

Editors:
J. S. Balirwa,
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Fisheries Resources Research Institute
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LAKE VICTORIA ENVIRONMENT MANAGEMENT PROJECT
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FOR MAXIMUM SUSTAINABLE BENEFITS

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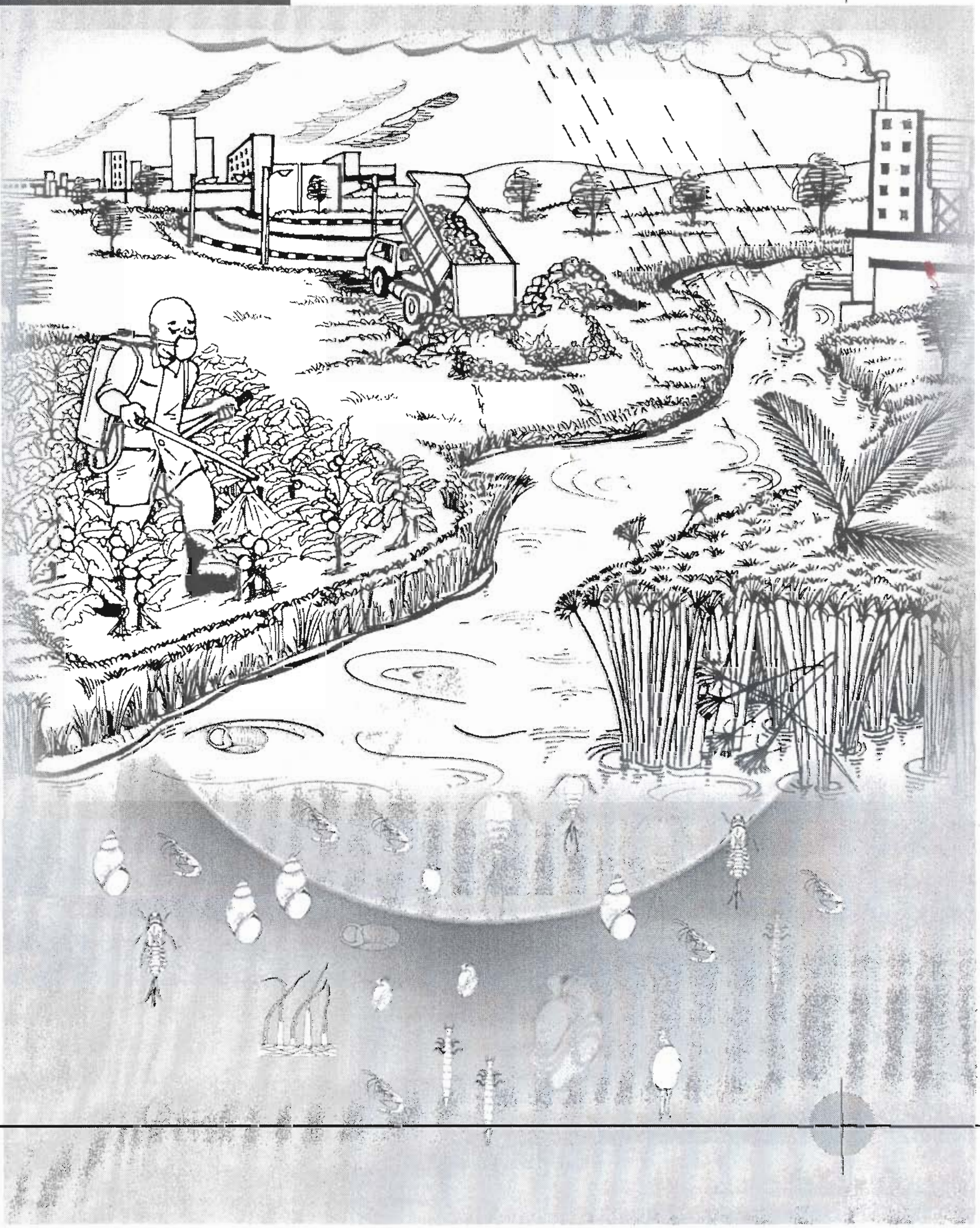
CHAPTER SEVEN 7

Management of Fish Habitat



7.1. Wetlands and riparian zones as buffers and critical habitats for biotic communities in Lake Victoria

Balirwa J.S, M. Nsega & S.K. Sekiranda

Introduction

Despite their ecological and socio-economic importance, Lake Victoria's adjoining "swamps" and lake interface are among the least investigated parts of the lake (Table 7.1.1). The "swamps" a term commonly equated to "wastelands" and the difficult working environment they present in comparison to open water, are major factors for the low level of attention accorded to shoreline wetlands.

Table 7.1.1. **Major ecological zones of Lake Victoria defined by spatial zonation patterns and % relative research effort in the literature**

Zone	% Research effort ± est S.D.
Swamp interior	5 ± 2
Lake interface (inner littoral)	5 ± 1
Riverine/Stream	10 ± 5
Outer littoral	10 ± 5
Sub-littoral	50 ± 5
Open lake	15 ± 5
Others (the deepest areas)	5 ± 5

(Based on rapid Survey of Lake Victoria Literature in FIRRI's library between 1950 and 1998 and Crul *et al.*, 1995)

Moreover, definitions of wetlands highlighted for example in the Ramsar Convention as "*areas of marsh, fern, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish, or salt, including areas of marine water, the depth of which does not exceed six metres*" (Ramsar, 1971) were designed to protect birds (water fowl) of international importance. The Ramsar definition, which also includes oceans, has till recently been of limited use for Lake Victoria, because it does not fully recognise wetlands in relation to other public concerns such as water quality, biodiversity and the fisheries that are of higher socio-economic priority than waterfowl.

Prior to 1992, fishery research on Lake Victoria included studies of inshore shallow habitats of the lake without specific reference to distance or the type of vegetation at the shore. Results of these studies also conveniently relied heavily on trawl and gill net data from the 5-10 m depth zones as the defining boundary of shallow inshore habitats. In Lake Victoria, such a depth range can be at least one kilometre from the lake interface and by the 10 m depth contour, habitats are in the sub-littoral range. Findings from these studies could thus not be used to make direct inferences on the then assumed importance of Lake Victoria wetlands in general. From 1993, structural components of the lake's littoral zone with particular reference to riparian vegetation, depth and fish populations have been studied (Balirwa, 1995; 1998). Other studies have addressed the efficiency of the lakeshore wetland vegetation in stripping nutrients from wastewater (e.g. Okia, 1993; Lizhibowa, 1995; Sekiranda, 1996; Sonko, 1996; Kaggwa, 1998; Kansiime & Nalubega, 1999) These studies have improved our understanding of Lake Victoria wetlands based on earlier studies of tropical swamps (Beadle, 1981; Gaudet, 1977; Howard-Williams, 1985).

Lake Victoria lakeshore wetland features

For lakes, ponds and rivers, the dominance of submerged and emergent plants, and, the penetration of sunlight up to the bottom of the water (Fig.7.1.1) provides a clearer illustration of "wetlands" (Odum, 1971). Still, the shallower (< 3m deep) Lake Victoria's riparian littoral zone with the emergent, floating and submerged plants and other features such as sandy and rocky beaches are part of the wetland zone (Balirwa, 1998). The lake is characterized by a 3440 km inundated and convoluted shoreline made up of a variety of vegetated littoral habitats referred to as swamps. With about 2000 km of this shoreline (including islands) length in Uganda, it is clear that when shallow (< 4m deep) regions of the lake are included among wetlands, the total wetland coverage would be much larger than is currently estimated. For Lake Victoria's wetlands in Uganda, the additional area amounts to at least 400 km^2 if a width of 200 m towards open water is considered.

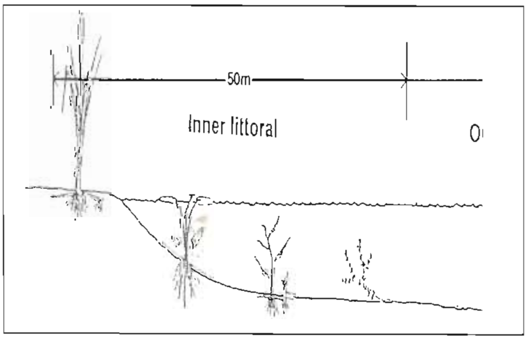


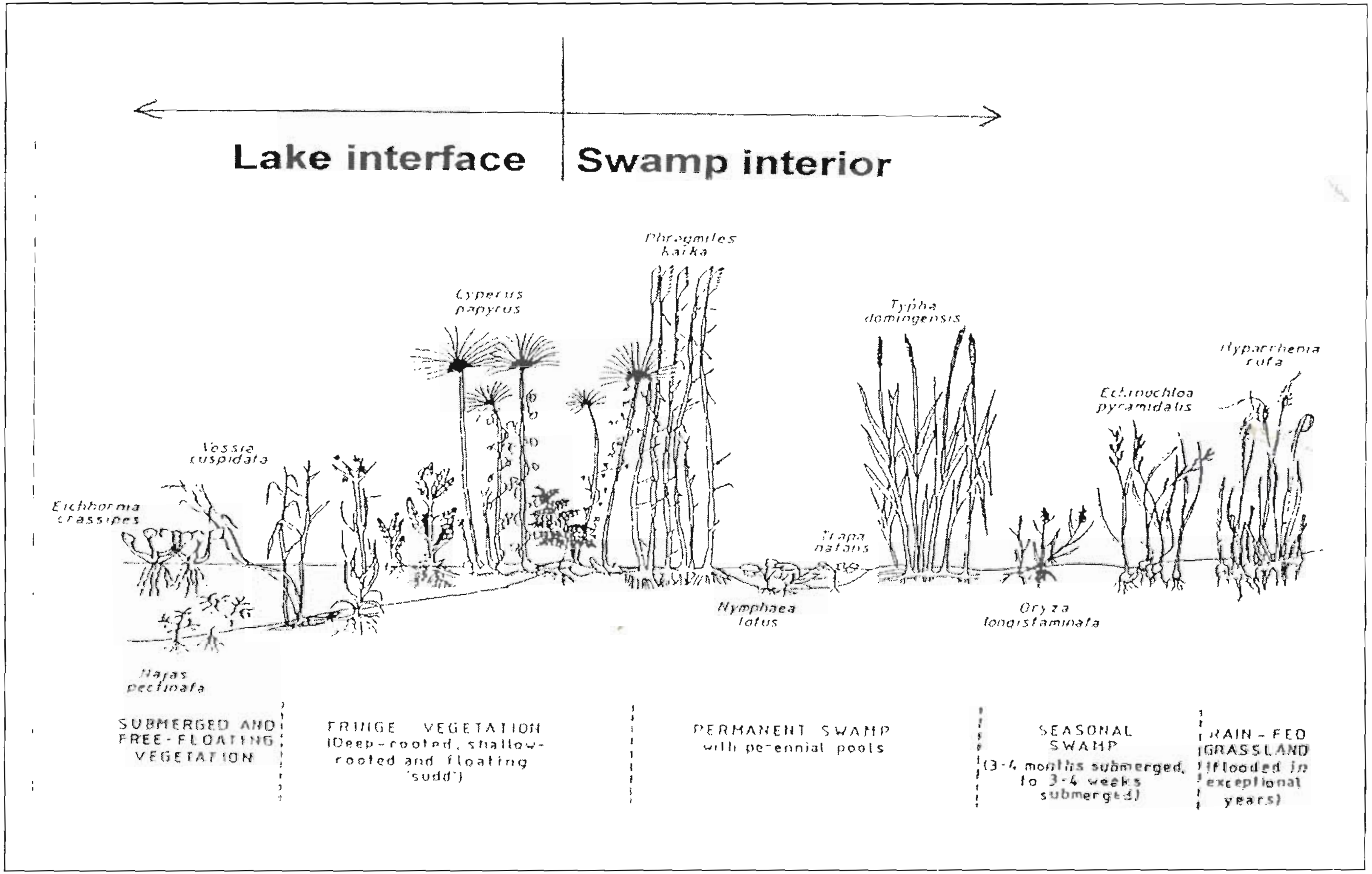
Fig. 7.1.1 Longitudinal transect through 350 m of Lake Victoria lakeshore wetlands

The plant communities of Lake Victoria wetlands are closely linked to the ecology of the lake (Beadle, 1981). Due to the geological history of Lake Victoria, the "wetlands" along the lake's shoreline are a combination of both permanent and seasonal swamps and are dominated by *Cyperus papyrus* L. (Papyrus), *Phragmites mauritianus* Kunth (reeds), *Typha domingensis* Pers. (Bulrush), *Miscanthidium*, *Afromomum* and swamp forest (Beadle, 1981). In these wetlands, dominance patterns of macrophyte species vary with distance from the shore along transects towards dry land (Fig. 7.1.2). The drainage patterns that characterize the lake basin are reflected in the numerous indentations (bays and gulfs) along the shore, and areas behind the swamp fringes that become lagoons especially during periods of above-average rainfall. At the lake interface, submerged and floating plants are common. In the more exposed areas of the shoreline are sandy and rocky beaches. Despite this complexity, four major inter-linked zones of the lake's shoreline can be recognized. These are: the swamp buffers, the interior of which supports little fish production, the macrophyte-dominated lake edges (i.e. the interface zone between the swamp buffers and open areas of the lake) (Fig. 7.1.2), the rocky and sandy stretches and the inflowing streams, which are important sites for fish breeding migrations. Important ecological functions can thus be attributed to Lake Victoria wetlands; these include water quality regulation, biodiversity and fish recruitment and production.

Lakeshore wetland characterisation

Based on macrophyte community dominance patterns, at least 12 macro-habitats types can be discerned: (a) *C. papyrus* (b) P. *mauritianus,* (c) *Vossia cuspidata* (Robx.)(Hippo grass), (d) *Sesbania sesban/ Aeschynomene*, (e) *Afromomum angustifolium,* (f) *Eichhornia crassipes* (water hyacinth) (a new but dynamic wetland community), (g) Forest-dominated types, (h) Disturbed-mixed vegetation types. The non-vegetation influenced macro-habitats include sandy and rocky shores and islands. The submerged and floating macrophytes (also known as euhydrophytes) are often locally dominant and distinguish particular micro-habitat types from the more dominant emergent species for example *Pistia stratiotes* (Nile cabbage), *Nymphaea caerulea* (water lily) and *Ceratophyllum* spp. Although they generally occur more frequently in the more sheltered and less turbid indentations of the lake, euhydrophytes (especially the submerged and leaf-floating species) can be used to define the lake ward boundary of the littoral zone. In such zones, secchi-depth is the same as total depth since light penetrates to the bottom. Since 1993, water hyacinth invaded the lakeshore and modified the wetland landscape with major implications for water quality, biodiversity and the fisheries.

Fig. 7.1.2. Structural features of lakeshore wetlands of Lake Victoria



Lake Victoria wetlands as water quality regulators and buffer zones

Major water quality issues for the Lake Victoria environment are the expanding urban centres and industrial activities along the lake shore that pose pollution problems. These problems are related to the flow of untreated industrial and municipal wastewater into the lake through parts of the previously wetland-dominated shoreline. The exposed parts of the shoreline are also avenues for silt from agricultural lands and garbage from human settlements especially urban centres.

Both natural and constructed wetlands are known to be passive alternative technologies to conventional treatment plants and studies have shown the ability of wetlands (both natural and constructed) to sequester, filter and assimilate pollutants as well as create a suitable environment for micro-organisms to transform the pollutants (Gaudet, 1977; Howard-Williams, 1985; Okia, 1993; Sonko; 1996; Sekiranda, 1996). Experimental mesocosms in which *C. papyrus* and *P. mauritianus* were tested (Table 7.1.2) show significant purification capacities by these plants. The nitrogen (N) and phosphorus (P) removal efficiencies of these plants were shown to vary between 50-90% depending on several factors such as inlet nutrient concentration, age of the plants and type of substrate.

Table 7.1.2. % Removal (Reduction) efficiency of Lake Victoria wetland plants subjected to wastewater

$$\% \text{ Removal} = \frac{\text{inlet concentration} - \text{outlet concentration} \times 100}{\text{inlet concentration}}$$

Parameter	Rooted *Phragmites mauritianus*		*Cyperus papyrus*	
	Inlet concentration	Mean % Removal	Inlet concentration	% Removal
BOD $mg.l^{-1}$	55 - 102	60.8	788	22 - 84
COD $\mu g.l^{-1}$	93 - 184	73.3	nd	nd
EC $\mu s.cm^{-1}$	930 - 1376	nd	300	87 - 92
SS $mg.l^{-1}$	40 - 137	79.9	94	54 - 64
TP $mg.l^{-1}$	0.4 - 5.9	92.4	5	nd
o-P $mg.l^{-1}$	0.2 - 4.3	92.7	25	95 - 100
NH4-N $mg.l^{-1}$	31.7 - 105.5	98.9	67	90 - 95

(Sources: Lizhibowa, 1995; Sekiranda, 1996. nd = no data)

Other substances removed by Lake Victoria's wetland plants include suspended solids (SS), BOD and conductivity (Lizhibowa, 1995). However, when the fringing wetlands are overloaded with wastewater and sludge, their purification efficiency decreases (Kaggwa, 1998). Since inflows are not evenly distributed throughout the wetland buffers, it seems that the plants' filtration capacity is not optimized. This is illustrated by measurements in the inner Murchison bay near Kampala where Acham (2002) recorded DO values of <2.0$mg.l^{-1}$ and electrical conductivity of 310 $\mu s.cm^{-1}$ at sites along opposite shores of the wastewater inflow. These data demonstrate the localized influence of wastewater in near shore areas adjacent to degraded wetland buffers.

The reduced efficiency of the Nakivubo swamp due to nutrient over-loads and papyrus harvesting has been reported by Kansiime and Nalubega (1999) as contributing to the poor water quality in Murchison bay.

Lakeshore wetlands and biotic communities with reference to fish

Lake Victoria is a major fishery resource and an area rich in other forms of biodiversity. The lake had till the 1970s a high species and trophic diversity with at least 500 endemic fish species (Witte & van Densen, 1995; Seehausen *et al.*, 1997) with the native inshore dwelling tilapiines (*Oreochromis esculentus* and *O. variabilis*) as the main stay of the fisheries. When the introduced fish species (especially the predatory Nile perch, *Lates niloticus*, which is currently an export commodity) had decimated most of the endemic species, the lake as a sanctuary of a diversified fauna and flora assumed global concerns (Kaufman & Ochumba, 1993). Because of the interest in the fisheries especially the impact of over fishing and that of the introduced species (Nile perch and the tilapiines), most references on the fisheries of the lake are about open waters especially the sub-littoral zone (5 - 10 m deep) where commercial fishing takes place. Following predation pressure due to an exponential increase in the introduced Nile perch stocks it has often been suggested that many species have become extinct (e.g. Ogutu-Ohwayo, 1990a, b; Witte *et al.*, 1992a, b). However, even though less quantified as resources of the lake, the riparian wetland buffers are as important for water quality and biotic communities as they are for the fisheries.

Table 7.1.3. A comparison of fish species % frequency of occurrence in shoreline macrophyte dominated habitats (within 100 m from the shore) and in habitats at 300 m away from the shore

Species	Habitat Type					No vegetation 300 m off
	Eichhonia	*Vossia*	*Typha*	*Cyperus*	*Phragmites*	
L. niloticus	86	100	96	100	100	100
O. niloticus	86	100	96	100	100	96
O. leucostictus	17	62	39	18	44	5
O. esculentus	-	-	-	-	6	-
O. variabilis	7	-	9	-	22	-
T. zillii	31	100	96	55	100	100
Astatoreochro	31	-	4	20	11	-
Alestes (Bycinus)	83	77	91	88	94	-
Protopterus	28	8	4	38	22	-
Gnathonemus	-	-	-	3	-	-
Mormyrus	-	-	26	3	28	-
C. gariepinus	-	-	-	-	-	-
C. alluaudi	-	-	-	-	-	-
C. carsonii	3	-	4	5	33	-
Bagrus docmak	-	-	-	3	-	18
Afromastacem	3	-	9	-	-	-
Synodontis	3	-	9	-	6	41
Barbus	-	-	-	-	11	-
Haplo. Ins.	48	92	61	48	67	27
Haplo. Zoo.	-	-	4	-	-	5
Haplo. Pisc.	28	92	70	45	67	32
Haplo. Moll.	-	-	-	-	6	-
Astatotilapia barabarae	-	-	4	-	-	-
H. lividus	-	-	-	-	-	-
H. nubila	-	8	4	13	-	-
Other haplos	-	-	4	3	-	5
Marcusenius	-	-	-	3	-	-
No. of taxa	13	9	18	16	17	10
No. of fishings	30	13	23	40	18	22

Astatoreochro. = *Astatoreochromis; Afromastacem.* = *Afromastercembelus;* Haplo. = Haplochromine, ins., zoo., pisc., moll., = insectivorous, zooplanktivorous, piscivorous, respectively trophic groups; (Source: Balirwa, 1998)

Studies carried out between 1993 and 1996 along the northern shores of Lake Victoria (Balirwa, 1998) revealed at least 27 fish species in the riparian vegetation-fringed habitats in comparison to 10 species in areas only 300 m away towards open water (Table 7.1.3). The more diversified vegetation-dominated habitats (*Typha, Cyperus* and *Phragmites*) contained between 16 and 18 species while the *Vossia-Eichhornia* habitat types supported only nine and 13 species respectively. The haplochromine fishes, which were not fully identified beyond trophic level in that study, could represent many more species thought to be extinct from the lake. The relative fish abundance (mean number of fish per ha) per habitat (Table 7.1.4) illustrates the habitats' importance One feature of the papyrus-dominated habitats in Lake Victoria was the presence of water hyacinth. In terms of the total number of fishes, water-hyacinth-papyrus infested habitats had a higher fish density than water hyacinth free papyrus habitats.

Table 7.1.4. The relative density of fish (mean no. ± S.E) of fishes per ha in 1"-5" gill nets set between 1994 and 1996 from vegetation- dominated habitats at the Lake Victoria interface. (S.E = Standard Error)

Habitat:	*Eichhornia*	*C. papyrus*	*Vossia*	*Typha*	*Phragmites*
Mean ± SE	116 ± 30b	49 ± 5 c	190 ± 26a	174 ± 25a	230 ± 41a
Range	5 - 733	18 - 146	48 - 369	36 - 448	45 - 663
N	22	32	12	19	15

N = number of fishing experiments in sites of each habitat type. Different letters (a, b, c, etc) denote significantly different means (Source: Balirwa, 1998)

Although the interior of hyacinth mats may not be expected to support much fish life except the lungfish (*Protopterus aethiopicus*), the observations illustrate the diversity of papyrus shores in terms of available fish habitats. A major conclusion drawn from these studies is that despite the presence of the introduced species (Nile perch and the tilapiines), the vegetation-dominated (i.e. lake shore wetlands) habitats still support numerous unidentified haplochromines and other endemic species (e.g. *Brycinus* and *Protopterus*) (Table 7.1.5). Even the native tilapiines and mormyrids thought to have disappeared from Lake Victoria are still found in riparian zones especially in the vicinity of the lake's streams. The rocky and sandy beaches still contain other endemic species including *Bagrus docmak, Labeo victorianus* and *Barbus altianalis*. The stocked species especially the tilapiines (*Oreochromis niloticus* and *Tilapia zillii*) can still be found in exposed areas of the shoreline off Typha and Phragmites fringes, a habitat similar to that once occupied by the native tilapiines.

Table 7.1.5. Numerical abundance of endemic species (% occurance) in comparison to the stocked species found in lakeshore vegetation-dominated habitats to the north of Lake Victoria

Habitat	% Relative abundance				
	Eichhornia	*Cyperus*	*Vossia*	*Typha*	*Phragmites*
Endemic spp:					
Brycinus	26	2	4	8	7
Astatoreochromis	7	1	1	1	1
Haplochromis	6	16	41	22	19
Protopterus	1	2	1	1	1
Others:	24	17	7	0	0
Exotic spp:					
Lates niloticus	16	39	16	10	10
O. niloticus	16	18	20	34	35
T. zilli	2	4	9	23	27
O. leucostictus	2	1	1	1	1
Number of fishes caught	87	52	175	172	232

Others: *Oreochromis variabilis, O. esculentus. Mormyrids, Clarias gariepinus, Afromastecembelus victoriae* (Source: Balirwa, 1998)

The rather extreme conditions of the dense swamp environment in the Lake Victoria basin (low dissolved oxygen, high levels of carbon dioxide, reducing conditions, detritus availability) affect aquatic organisms and determine, in part, the unique assemblages that characterize these habitats. The richness of animal life in the dense interior of papyrus and *Miscanthidium* swamps tends to be less than the ecotonal wetlands where interaction with the main lake waters raises dissolved oxygen levels and lowers carbon dioxide content. However, there are several aquatic taxa that possess adaptations (physiological, morphological, and behavioural) facilitating survival in the dense swamp interior to the respiratory challenges imposed by oxygen scarce waters.

The few accounts of papyrus and *Miscanthidium swamp fish faunas* in Lake Victoria include many air breathers (*P. aethiopicus, Clarias* spp., *Ctenopoma muriei* (Carter, 1955; Welcomme, 1970; Beadle, 1981; Chapman, 1995; Chapman & Liem, 1995; *Chapman et al., 1996). Some species like the lungfishes (P. aethiopicus)* are obligatory air-breathers while other species, including the air-breathing *Clarias*, have well-developed gills and can meet their oxygen requirements using water breathing at higher oxygen levels. Although air-breathing fishes are common in dense East African swamps, there are also several non-air-breathing fishes that cohabit these extremely hypoxic habitats. These fishes show a diversity of adaptations (e.g., high haemoglobin, aquatic surface respiration, large gills) that increase their oxygen uptake capacity (Chapman & Liem, 1995, Olowo & Chapman, 1996). Welcomme (1970) reported several non-air breathing fishes in the wetland lagoons that were produced between 1961 and 1964 behind the fringing swamps of Lake Victoria when water levels increased abruptly. Therefore, papyrus swamps are important in minimizing faunal mixing by creating barriers to the dispersal of fish species that are intolerant of low oxygen (Chapman *et al.* 1996, Schofield & Chapman, 1999; Rosenberger & Chapman, 1999).

Socio-economic utilisation of Lake Victoria wetlands

The lake shore wetlands have undergone considerable hydrological and geographical changes, initially following a rise in lake level in 1960/62 (Welcomme, 1965) and during the *last decades, an increase in* the human population in the catchment. Lagoons in the lake region were common wetland features following the el-nino rains of the 1960s and created new fish habitats that were associated with improvements in tilapia stocks (Welcomme, 1965). Similar conditions between 1997/1998 appear to have favoured fish stocks of Lake Wamala and a re-appearance of endemic fish species in wetland regions of both the Victoria and Kyoga basins. However, current utilisation practices of the lakeshore wetlands may not be sustainable for fish diversity as the population further expands and settlements increase along the shores.

Historically, local people relied on lakeshore wetlands as their principal water supply and source of protein (fish); they used the wetlands for livestock grazing and to obtain materials for building, furniture, and other needs. The traditional uses provide an example of sustainable use, because they allow both the communities and wetlands to thrive. Various aspects of wetland utilisation take into account socio-economic and ecological values. The socio-economic values include their use as agricultural land (for both small scale and large scale farming) and products (e.g. the use of wetland plants as medicines, building materials, or as sources of fodder for animals and as fishing areas, etc). To these can be added other unquantifiable socio-economic values such as water sources, flood control for large quantities of storm water etc.

Many human exploitation activities in the lakeshore wetlands are sustainable; however, an expanding and accelerating trend is large-scale drainage and conversion to large tracts of agricultural land. Wetlands are also threatened by irrigation schemes, industrial pollution and sand or clay mining. On a more local scale, overexploitation occurs in the context of harvesting resources like clay for bricks, building and pottery and papyrus for thatching houses and making carpets/ mats. Repeated gardening and cultivation or clearing fresh land for more areas to grow produce; over grazing of cattle in the wetlands, and small-scale burning by individual farmers also degrade localised patches of the wetlands.

The socio-economic uses of Lake Victoria's lakeshore wetlands have become rapidly diversified. In the vicinity of urban centres (e.g. Kampala, Jinja) the outer fringes of the lakeshores are used as dumping grounds for garbage and for municipal wastewater treatment. In the last few decades, filling in lakeshore wetlands has enabled extensive developments at the lakeshore that include industries, hotels, residential units and recreation facilities. Therefore, large-scale conversions of the remaining lakeshore riparian zones is likely to lead to further deterioration in water quality and disruptions in biotic communities especially fish habitats unless conservation measures are practiced.

The use of legislation for wetland protection

Although the observed wetland conversions may directly contribute to rapid economic gains from the investments, there is need to carry out economic analyses of environmental impacts of the investments in the riparian zones on the ecological functions. The dangers of further water deterioration and collapse in the fisheries will remain a constraint to investments in the sector.

There are adequate provisions in the law that could provide protection to wetlands in general. For example The Public Health Act 1935 and The Public Land Act, 1962 protect watercourses and swamps from obstraction, diversion and pollution. More recently, the 1995 Uganda Constitution provides adequate measures for the protection and utilization of wetlands under Chapter 15 concerning Land and Environment.

Legislation can be used to effectively regulate wetland utilization in various ways. For purposes of general usage and application of relevant legislation, The Uganda National Wetland Policy (1995) defines wetlands as "areas where plants and animals have become adapted to temporary or permanent flooding by saline, brackish or fresh water". The National Environment Statute (1995) defines wetlands as "areas that are permanently or seasonally flooded by water where plants and animals have become adapted", and both the Policy and Statute provide guidelines for the sustainable management of wetlands of local, national and international importance. In addition, the Water Statute of 1995 empowers Government to control, protect and manage water in Uganda for any use while the Land Act of 1998 regulates the utilization of land in conformity with various environmental statutes such as the Forest and Mining Acts. The provisions in the legislation require The Government or Local Government to hold in trust for the people and protect natural lakes, rivers, ground water, natural ponds, natural streams, wetlands, forest reserves, national parks, and any other land reserved for ecological and tourist purposes for the common good of the citizens of Uganda. The Wetland Policy is even more explicit: "There will be no drainage of wetlands unless more important environmental management requirements supersede; only those uses that have proved to be non-destructive to wetlands and their surroundings will be allowed and/or encouraged. These include water supply, fisheries, wetland edge gardens and gardens and grazing".

Despite the legislation, the rate of water quality deterioration and disappearance of some species of fish in Lake Victoria seem not to have been considered as a result of wetland degradation. According to Wetlands and the Law (2002), there are no statutory regulations for defining the identification or demarcation of wetland boundaries. For Lake Victoria, it is important to consider wetlands as buffers and critical habitats for biotic communities with boundaries. The provisions within legislation should be applied to ease pressure on lakeshore wetlands.

Conclusions and recommendations

1. The wetland-dominated interface of Lake Victoria is not a homogenous landscape (some areas are papyrus, hippo grass, reeds, water hyacinth, others are forested or mixed-vegetation dominants, etc). From these habitat types, there are significant differences among and between shoreline wetland-dominated habitats and the areas further away towards open water in terms of water quality and biotic communities.