Uganda Journal of Agricultural Sciences, 2003, 8 : 239 - 244 ISSN 1026-0919
Printed in Uganda

Proliferation, impacts and control of water hyacinth in Uganda

T. K. Twongo, F.M. Wanda and K.O. Odongkara
FIRRI, P.O. Box 343, Jinja, Uganda

Abstract

Water hyacinth invaded Lake Victoria and Lake Kyoga in Uganda during the second half of the 1980's and was firmly established by the end of that decade. During the 1990's, the weed spread rapidly, multiplied profusely and adversely impacted aquatic resources and services such as fisheries and fishing activities, availability of potable water, hydropower generation, transportation by water, and recreational and tourist facilities. The impacts of water hyacinth constrained efforts, which directly contributed to poverty reduction in the country. This paper highlights the contribution of research in Uganda to the control of the noxious weed. Research focused on understanding the processes and mechanisms of water hyacinth distribution, establishment and proliferation; the dynamics of migratory movements of weed mats; the environmental and socio-economic impacts of water hyacinth; the role of various control efforts, and the impacts of control measures. Data was compiled through regular surveillance and from field experiments. Distribution and establishment of water hyacinth was influenced by direction of regular winds and water currents; and by availability of shelter and environments with suitable nutrient-rich water depth and bottom substrate along the shore. The initial proliferation of water hyacinth gave rise to extensive stationary strips, which ultimately fringed about 2200 ha of shoreline length of Lake Victoria in Uganda, 570 ha of the shore of Lake Kyoga, and 500 ha along River Nile (in Uganda). Proliferation of mobile water hyacinth occurred in sheltered bays, particularly in Murchison, which is enriched with nutrients notably phosphorus. Maximum cover of 1800 ha of the mobile weed was estimated in Lake Victoria – Uganda. Mobile water hyacinth cover was distributed from the production bays to several storage bays through annual weed migrations across Lake Victoria. Control of the weed was achieved through the effects of biological control with *Neochetina* weevils, ecological succession dominated by native macrophytes especially hippograss, and by physical biomass removal at selected sites of socio-economic importance. The effects of biological control and environmental stress led to unprecedented collapse and sinking of huge biomass of mobile water hyacinth resident in the collection bays. Decomposition of the sunken water hyacinth caused prolonged depression of dissolved oxygen to anoxic levels close to the lake bottom, led to elevation of soluble reactive phosphorus, and to increased diversity and abundance of phytoplankton, macro-invertebrates and fishes. Water hyacinth was brought under control by the end of 1998 in most infested water systems of Uganda except rivers Kagera and the Nile. In the year 2000, persistent weed resurgence occurred in environments rich in phosphorus notably in Murchison Bay. Control of water hyacinth in rivers and nutrient enriched environments is key to the management of the weed in Uganda.

Key words: water hyacinth, proliferation, impacts, control.

Introduction

Water hyacinth, *Eichhornia crassipes* (Mart) Solms, is a free-floating waterweed native to the Amazon *River basin* of South America, where it is kept in check by natural enemies and the regular fluctuations of stream and river levels. Mainly in admiration of its beautiful flower, the plant was extensively introduced outside its native range and became probably the most troublesome waterweed in the tropical and sub-tropical world. In Africa, water hyacinth is a serious weed, widespread in countries ranging from Egypt to South Africa (Harley, 1993). The weed is thought to have gained access to the

Nile River basin in Egypt between 1872 and 1892. Water hyacinth was reported in lakes Kyoga – Uganda, Naivasha – Kenya, and in Lake *Victoria* (shared by Kenya, Uganda and Tanzania) at about the same time, in the late 1980s (EAC, 1999).

Infestations of invasive waterweeds such as water hyacinth often involve enormous biomass proliferation and severe socio-economic and environmental impacts, prompting the need to mobilise resources to effect control. In Uganda, the adverse impacts inflicted by water hyacinth biomass on aquatic resources and associated services such as fisheries, and fishing activities, availability of potable water to lake-side communities, hydropower generation, transportation by water, and recreational and tourist facilities demonstrated the serious constraints proliferation of the weed could impose on the success of efforts towards poverty reduction. The resources and services impacted benefited a wide range of national socio-economic interest from the rural poor to the industrialist. This paper highlights the effort made by research under the National Agricultural Research Organisation, NARO, as a contribution to the management of water hyacinth. The purpose of the research was to understand the processes and mechanisms which influence water hyacinth distribution, establishment and proliferation; the dynamics of the migratory movements of weed mats; the environmental and socio-economic impacts of water hyacinth; the role of various control efforts, and the environmental impacts of control measures. It was expected that the information from the research would be used to guide formulation and review of weed control strategies.

Materials and methods

Information on water hyacinth was compiled through observations during periodic surveillance and from field experiments spanning a period of over ten years since 1989. This paper is comprised by a selection of that information. Surveys covered shores and bays of lakes Victoria and Kyoga as well as River Nile using methods described by Twongo et al (1995), given here in outline. To estimate the area covered by stationary water hyacinth along the shore, the extent, in length, of the infestation was demarcated and measured on a map. The width of the stationary fringe was averaged from several independent approximations. The area of large mobile fields of the waterweed was similarly mapped in the evening when diurnal landward breezes had piled it along the shoreline. The area of smaller water hyacinth mats was calculated from estimated dimensions: the width was often averaged from four independent estimates made by eye; the length was obtained from a timed steady run by canoe and outboard motor whose speed was established under prevailing weather conditions. The area of the waterweed along sparsely and intermittently infested lakeshores was estimated by averaging several independent visual estimates. The average width of the water hyacinth along the Nile was estimated while sailing down portions of the river and the total length of the fringed shorelines was extrapolated from measurements on a map, based on identified features, notably presence of fringing papyrus wetlands, which indicated portions of the river with potential for infestation with water hyacinth (Twongo et al., 1995). A survey of River Nile in 1992 established that most shore environments with that potential had been fully infested with the weed. Socio-economic impacts were identified through a sample survey using a structured questionnaire, key informant interviews, and direct observations. The survey was conducted at 14 sites on Lakes Victoria and Kyoga in 1996-97 and involved 760 respondents from the shoreline communities. The key informant interviews involved the use of an open-ended interview schedule and were targeted at heads of the establishments. A series of studies were conducted to determine the environmental/ ecological impacts of the weed (Willoughby et al 1993; Willoughby et al., 1996; Twongo et al., 1992; Twongo, 1996; Twongo and Balirwa, 1996; Wanda, 1997; Balirwa, 1998; Wanda et al., 2001). The process to control water hyacinth in Uganda evolved systematically through four main phases namely development of institutional arrangements, control strategy formulation, verification of control options, and implementation of the control strategy. This paper will be restricted to examples of research input into the control process.

Invasion, distribution and proliferation

Presence of water hyacinth was first reported in Uganda in May 1988, at two locations in Lake Kyoga (Twongo, 1991). Distribution of the weed along the shores of Lake Kyoga was aided by the general east to west water flow regime of the lake, which also distributed the viable units of the weed down River Nile and to Lake Albert by 1990. On its way down the Nile, the weed was fragmented at major waterfalls such as Karuma and, especially, Murchison. The viable units of the fragments greatly facilitated the initial propagation process downstream. Shelter from offshore and along-the-shore winds, water depth of less than 5 m and a muddy bottom favoured weed establishment. Presence of a fringe of papyrus (*Cyperus papyrus*) and stands of hippograss (*Typha domingensis)*, or *Sesbania spinosa*, was a predictor of environmental potential for the establishment of the weed along the shore (Twongo *et al.*, 1992). Water hyacinth was first reported in the Uganda sector of Lake Victoria in 1989, when the weed was already widely distributed along the western shoreline (Taylor, 1993). Water hyacinth in the Tanzanian portion of River Kagera in 1987 and appeared in Lake Victoria -Tanzania a year later (Malya, unpublished report). The source of the infestation in the

Kagera is believed to be Rwanda where the weed occurs in the Nyabarongo in Ruhengeri (Twongo & Winberg, 1999) and the Akanyaru, the main upper tributaries. Water hyacinth got established in the suitable macro habitats around lakes Kyoga and Albert, and the shores of River Nile by 1990; and in Lake Victoria - Uganda by 1991. Establishment of the weed along the extensive shoreline of Tanzania and Kenya was probably completed by 1993.

Two distribution patterns of water hyacinth namely stationary fringes along the shoreline and mobile mats located predominantly in sheltered bays and propelled about by winds and water currents were identified. Proliferation of the stationary weed peaked in Lake Kyoga and the Nile River in 1994 at 570 ha and 500 ha, respectively. In Lake Victoria maximum stationary fringes dominated by water hyacinth reached 2200 ha by 1995. Mobile water hyacinth in Lake Kyoga was scattered and continuously floated into the Nile current and down River Nile where it was fragmented by waterfalls particularly the Murchison. Sustained proliferation of mobile water hyacinth in Lake Victoria–Uganda occurred predominantly in inner Murchison Bay from where it was exported to three main sheltered storage bays of Thruston, Hannington and Waiya. Maximum standing cover of the mobile weed in Lake Victoria – Uganda was estimated in 1998, at 1800 ha while that in the Kenya and Tanzania portions of the lake was estimated at 6,000 and 2,000 ha, respectively (EAC 1999).

Nutrients and proliferation

The role of nutrients in water hyacinth proliferation in Lake Victoria is the subject of on-going in-depth research at FIRRI. However, temporal patterns of weed biomass (Table 1) and more recent data for Soluble Reactive Phosphorus (SRP) given in the last column of the table provide some tentative comparisons. The initial proliferation of water hyacinth in Uganda occurred in most sheltered bays of Lake Victoria including Murchison, Bunjako, Macdonald and Pringle (Fig 1). Subsequently, proliferation in most bays, for example Macdonald and Pringle, declined considerably. Murchison Bay remained the most prolific water hyacinth production bay in the country, maintaining high weed biomass cover. It should be noted that large quantities of water hyacinth biomass were evacuated annually from this bay to the open lake by violent storms associated with strong winds, during the last four months of the year. The evacuated weed biomass was translocated into Waiya, Thruston and Hannington bays through lengthy migratory movement across the open Lake (Twongo et al., in prep), The migrations and storage were reflected in progressive accumulation of water hyacinth biomass in the three bays. Significant water hyacinth proliferation was not observed in the three bays hence the tag 'storage bays'. The following conclusions appear to describe the relationship between the proliferation of water hyacinth in the bays and the corresponding mean SRP levels in Table 1. The high levels of SRP recorded in inner Murchison Bay appear to have fueled the proliferation of water hyacinth to produce consistently high cover in the bay till 1998, in spite of the annual weed evacuation from the bay. Mobile water hyacinth in Lake Victoria, Uganda was brought under control at the end of 1998. It is also suggested that the initial proliferation of water hyacinth in the originally productive bays such as Macdonald and Pringle (see Table 1) was supported by a stock of nutrients, which was progressively depleted. Water hyacinth cover in Namirembe Bay was not monitored until after weed resurgence of the year 2000. The

Table 1. Changes in the cover (ha) of mobile water hyacinth in production and storage bays in northern Lake Victoria - Uganda Lake Victoria, Uganda in relation to environmental levels of Soluble Reactive Phosphorus (SRP - $\mu g l^{-1}$).

Location (Bays)	1994	1997	1998 (May)	1998 (October)	1999	2001	Mean SRP
MurchisonÅ	877	490	100		<2	10	425
Namirembe	ND	ND	ND	ND	ND	4	92
Waiya*	3	80	140	20	<1	<0.5	7.8
Thruston*	108	790	800	30	<1	<1	9.7
Hannington*	96	304	750	300	<1	<1	12.0
Macdonald	13	4	<2	<2	<1	<1	12.5
Pringle	15	5	<1	<1	<1	<1	14.5
Total cover	**1,112**	**1673**	**1, 793**	**353**	**<8**	**<18**	

Å Major production centre; * Major storage bays; ND = Not determined.

Source: Twongo et al. (in prep)

significant persistent weed resurgence in this bay in 2001, as well as the one noted in inner Murchison Bay, would be consistent with the high levels of mean SRP recorded in the two bays. On the other hand, preliminary data on the levels of SRP in riverine environments such as Kagera and the Nile do not adequately account for the consistently high proliferation of water hyacinth in those environments.

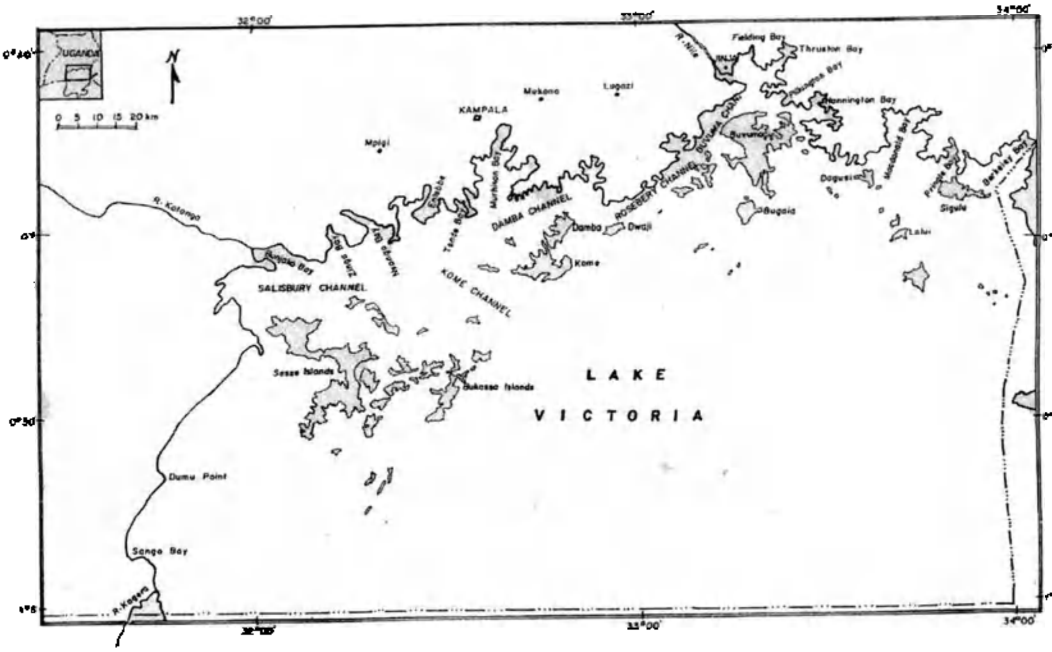
Impacts of water hyacinth proliferation

The devastating impacts Water hyacinth inflicts on human interests are used to qualify the weed as the most notorious aquatic *weed*. Impacts due to infestation by the waterweed in lakes Victoria and Kyoga were classified into socio-economic and ecological/ environmental (Twongo et al., in prep). Weed biomass severely impacted large scale water abstraction and treatment, access to clean potable water by lakeside communities, fishing activities, navigation, and hydro-electricity generation. Recreational facilities along beaches were also smothered by the weed or fowled by deposits of mud and decaying water hyacinth biomass. The impacts often involved loss of resources or necessitated considerable unplanned investment. On the other hand proliferation of water hyacinth had some positive attributes. The national drive to control the weed manually was a source of employment to some lakeside communities (Odongkara, 1995 & 1997).

Most studies on ecological impacts were made in the stationary fringes of water hyacinth (Willoughby et al., 1996; Twongo & Balirwa, 1998; Wanda, 1997; Balirwa, 1998; Wanda et al., 2001). Extensive, tightly packed water hyacinth mats along the shoreline impaired environmental quality for biodiversity maintenance, fish breeding, nurseries of young fish, and for feeding and shelter of fishes. The interior of extensive mats particularly the stationary ones were typically deoxygenated or had low levels of oxygen and produced other poisonous gases like ammonia (Wanda, 1997) and probably hydrogen sulphide. Water hyacinth mats accumulate silt in the roots and deposit it together with weed debris wherever they are anchored temporarily or are permanently growing. The above unfavourable environments appear to be responsible for the low species diversity associated with the interior of extensive cover of water hyacinth. For example, Wanda et al (2001) attributed the paucity of macro-invertebrates in the interior of large stationary weed mats to unfavourable environmental conditions such as low dissolved oxygen, although some typically low oxygen tolerant groups such as chironomids (Chironomidae) and earthworms (Annelida) were found in large numbers. Proliferation of stationary weed cover and migration of extensive mats on to usually productive shore environment are, therefore, likely to be detrimental to biodiversity and fisheries attributes such as beds of water plants, macro-invertebrate communities and to fish spawning, nursery, and feeding grounds commonly present in shallow inshore lake zones.

Some positive attributes were associated with narrow shoreline stationary fringes of the weed. For example, the fringes sheltered biodiversity (life in water) ranging from encrusted algae and macro-invertebrates

Figure 1.



to young and small sized fishes. Such taxa often occurred in large numbers. Similar biodiversity was found in small mobile mats and at the edge of more extensive stationary and mobile mats. Those environments were rich feeding grounds for fish and other organisms and the mats are believed to have dispersed biodiversity as they drifted about the lake. Preliminary information on the impact of sunken water hyacinth in the storage bays of Lake Victoria Uganda (see section on weed control) indicate advantages and disadvantages. The sinking of the massive biomass appears to have been associated with prolonged oxygen depletion in the bottom waters of the affected bays as well as with temporary decline in biodiversity, followed by enhanced biological productivity and a vibrant but apparently short-lived or seasonal fishery. Detailed reports on the impacts of sunken water hyacinth will be published in due course.

Control of water hyacinth

The process to control water hyacinth in Uganda evolved systematically through four main phases namely establishment of institutional arrangements, control strategy formulation, verification of control options, and implementation of the control strategy. This paper highlights some of the research related aspects in which scientists of NARO were involved. Formulation and implementation of the research aspects of the control strategy was spearheaded by the NARO through the National Technical Committee on Water Hyacinth (NTCW). The major outputs of the NTCW were formulation of the "Action plan for control of Water hyacinth in Uganda"; consolidation of research as an essential input into the water hyacinth control process; screening of *Neochetina* weevils for specificity as biological control agents, initiation of biological control of water hyacinth in Lake Kyoga and later in Lake Victoria; and the supervision of laboratory scale and pond based experiments to verify efficacy and environmental friendliness of various candidate herbicides for water hyacinth control.

Role of biological control

Three processes namely biological control augmented by environmental stress, ecological succession between the weed and native water plants, and physical removal of water hyacinth at selected locations using mechanical and manual means were involved in the control of water hyacinth in Uganda. Control of mobile water hyacinth in Uganda was achieved through the use of two species of biological control weevils namely *Neochetina eichhorniae* and *Neochetina bruchi*. The biological control weevils were introduced in 1993 and 1995/96 in lakes Kyoga and Victoria, respectively and control of the mobile component of the weed was achieved through progressive biomass decay and sinking about three years later. The unprecedented success of biological control in Lake Victoria, Uganda generated considerable speculation regarding other possible causes. However, the speculations were dampened when processes similar to those reported in Uganda destroyed mobile water hyacinth in the Kenyan and Tanzanian portions of the lake about two years later. It is pertinent to note that in the Uganda portion of Lake Victoria, mobile water hyacinth accumulated in the storage bays for up to four years with little evacuation at any one time. Establishment of the weevils occurred first in these bays and severe loss of condition was noted only among mobile mats. Stationary mats in the bays remained little infected by the weevils until after the mobile mats sunk. It is proposed that prolonged residence of water hyacinth in the storage bays stressed the plants and rendered them more vulnerable to the effects of biological control, which included secondary attack by other pathogens like fungi and macro-invertebrates. The underwater components of the mobile mats progressively suffered serious physical deterioration and were virtually rotten when they collapsed and sunk under the influence of strong wind-induced turbulence.

Role of ecological succession

Ecological succession in this context was a process whereby native plants initially co-existed but eventually displaced stationary water hyacinth along the shore. The process contributed to the control of water hyacinth through progressive displacement of the shoreline mats basically by shading off light and possibly out-competing the weed for nutrients. The dominant competitor in the succession was hippograss *(Vossia cuspidata)*, although other aquatic plants such as the sedge *Cyperus mundtii*, were dominant in some isolated enclaves. Ecological succession displaced most of the estimated 570 ha of stationary water hyacinth in Lake Kyoga. In Lake Victoria, succession displaced at least 70 % of the total length of the stationary shoreline fringe of water hyacinth by 1998. It is therefore, proposed that in the long run, ecological succession was equally important a control measure in Lake Victoria, Uganda as biological control. Ecological succession was the principle control measure in Lake Kyoga, which did not have extensive cover of mobile water hyacinth. The role of mechanical control, which was targeted to specific landing sites, is not discussed in this article.

Recommendations

1. Water hyacinth in the lakes of Uganda was controlled by biological control weevils, ecological succession and selective physical weed removal. The weed in rivers Kagera and the Nile resisted control by biological means. Ecological studies are proposed to understand the causes of the resistance to biological control. Studies would focus on relating aspects of weed biology, weevil biology, and environmental factors including nutrients, to the effectiveness of biological control.

2. Water hyacinth proliferation in Lake Victoria basin is fuelled by nutrients originating mainly from catchments. The resurgence now underway in the Uganda portion is sustained mainly in the nutrient-enriched Murchison Bay. It is recommended that reduction of nutrient loads from land-use activities into aquatic ecosystems be a long term planning objective towards the management of water hyacinth.
3. An effective community based surveillance system to identify and report resurgence of water hyacinth should be developed.

Acknowledgement

Several research scientists and many technicians and support staff at the Fisheries Resources Research Institute, Jinja, contributed to the collection of data and information used to write this paper. We acknowledge their collective input. The Government of Uganda provided the most consistent funding for this research. The research was also supported at various times, by the IDA/IFAD loan for the Agricultural Development Project (ADP) of Northern and Eastern Uganda, and the IDA loan for the Lake Victoria Environmental Management Project (LVEMP).

References

Balirwa, J.S. (1998). Lake Victoria Wetlands and the Ecology of the Nile tilapia, *Oreochromis niloticus* Linne. Ph.D. Thesis.

EAC, 1999. Regional strategy for the control of water hyacinth and other invasive weeds in East Africa. East African Regional Cooperation, Arusha.

Odongkara, O.K, 1997. Effect of water hyacinth on earnings of fishers. Paper presented to the Scientific Seminar on Water Hyacinth Research in Uganda. Windsor Lake Victoria Hotel, Entebbe - 8 July, 1997.

Odongkara, O.K., 1995. Community participation: report of the consultation for the promotion of stakeholder partnership in Uganda; Lake Victoria Environment Managment Programme: UNDP RAF/93/G41.

Odongkara, O.K. 1997. FIRI Fish Commodity system economics (U) project final technical report, NARO

Harley, k. (1993). Commonwealth Science Council Survey Project on exotic floating African water - weeds: Survey Report. In: Greathead A & P de Groot (1993) Control of Africa's Water Weeds. Series Number CSC (93) AGRI 18 Proceedings 295.

Taylor, A.R.D. 1993. Floating water-weeds in East Africa, with a ease study in Northern Lake Victoria. In: Greathead A & P de Groot (1993) Control of Africa's Water Weeds. Series Number CSC (93) AGRI 18 Proceedings 295.

Twongo T.K., 1991. Water hyacinth on Lakes Kyoga and Kwania. Special report No. 3, November 1991, for FAO TCP/UGA/9153/A. In Thompson K. (ed): The water hyacinth in Uganda, ecology, distribution, problems and strategies for control. proceedings of national workshop, 22-23 October, 1991. FAO TCP/UGA/9153/A, Kampala, Uganda.

Twongo T.K., F.W. Bugenyi & F. Wanda, 1992. Potential for further proliferation of water hyacinth in Lakes Victoria and Kyoga, and some urgent aspects for research. At sixth session of FAO CIFA sub-committee for development and management of the fisheries of Lake Victoria, 10-13 February, 1992, Jinja Uganda.

Twongo, T.K., F.W.B. Bugenyi; and Wanda, F. 1995. The Potential for further proliferation of water hyacinth in Lakes Victoria, Kyoga and Kwania and some *urgent aspects of research.* Afr. J. Trop. Hydrobiol. Fish. Vol. *6 (No. 1&2). pp1*-10.

Twongo, T., 1996. Growing impact of water hyacinth on near-shore environments of Lakes Victoria and Kyoga (East Africa). In Thomas C. Johnson and Eric O. Odada (Eds). The limnology, climatology and paleoclimatology of the East African Great Lakes. Gordon and Breach Publishers, pp 633-642.

Twongo, T., and J. S. Balirwa. 1996. Influence of water hyacinth on the ecological character of shoreline wetlands of Lake Victoria (East Africa). At Technical Session B. Sixth Meeting of the Conference of the Contracting Parties, Ramsar Convention, risbane Australia, 19-27 March 1996. Ramsar convention Bureau. Reports and presentations Vol. 10/12.

Twongo, T. 1999. Impact of water hyacinth in Lakes Victoria and Kyoga, a case study. In Report of the Thirteenth Global Biodiversity Forum 1999. San Jose Costa Rica. IUCN The World Conservation Union.

Twongo T, and Winberg, R. 1999. A rapid appraisal of the water hyacinth problem in Rwanda, RELMA – Sida, Nairobi.

Wanda, F.M. 1997. The impacts of water hyacinth Eichhornia crassipes (Mart) Solms on the abundance and diversity of aquatic macro-invertebrates in northern Lake Victoria, Uganda. M.Sc. Thesis, IHE, Delft, The Netherlands.

Wanda, F.M., T. Twongo & P. Denny, 2001. The impacts of water hyacinth Eichhornia crassipes (Mart) Solms on the abundance and diversity of aquatic macro-invertebrates along the shores of northern Lake Victoria, Uganda. Hydrobiologia 452: 79-88.

Willoughby, N.G., I.G Watson, S. Laver and I.F Grant. 1993. The effects of water hyacinth on the biodiversity and abundance of fish and invertebrates in Lake Victoria, Uganda. Final Technical Report. NRI Project Nos. 10066 & A0328. Natural Resources Institute, Overseas Development Association. United Kingdom.

Willoughby, N.G., I.G. Watson and T. Twongo, 1996. Preliminary studies on the effects of water hyacinth on the diversity, abundance and the ecology of fish fauna in Lake Victoria, Uganda. In Thomas C. Johnson and Eric Odada (Eds). Proceedings of Symposium: The Limnology, Climatology and Paleoclimatology of East Africa Lakes. 18-22 February 1993, Jinja, Uganda.

Uganda Journal of Agricultural Sciences, 2003, 8 : 231 - 238 ISSN 1026-0919
Printed in Uganda

Conservation of fish species diversity in the Victoria and Kyoga lake basins

Namulemo Gertrude, Ogutu-Ohwayo R., Wandera S.B and Mbabazi D.

Abstract

Fish species diversity in lakes Victoria and Kyoga has declined and some species, especially of haplochromines and *Oreochromis esculentus* are believed to be extinct. A survey was carried out in a number of satellite lakes and an inventory made of the existing fish species, their relative abundance and distribution. The lakes studied included the Kyoga minor lakes, Nabugabo lakes, the Koki lakes and L. Wamala. Various habitats within the main lakes Victoria and Kyoga were also surveyed. Various stations along rivers Nile and Sio were also sampled. A total of twenty-one fish taxa were recorded from Kyoga minor lakes as compared to eighteen recorded from Lake Kyoga. Lake Nyaguo had the highest number of fish taxa (14), followed by lakes Nakuwa (12), Nawampasa (11), Lemwa (10), Agu (9), Kawi (8), and Gigati (7). The number of haplochromine species was highest in L. Nawampasa (23) followed by lakes Gigati (18), Agu (11), Nyaguo (10), Lemwa (8) and Nakuwa (2). Fourteen fish taxa were recorded from the Nabugabo lakes, the highest number being from L. Nabugabo (13) followed by lakes Kayanja (11) and Kayugi (7). Four haplochromine species were recorded from Nabugabo lakes From Koki lakes eight fish taxa were recorded, Lake Kachera having a higher number of species (8) than L. Mburo (6). A total of 9 fish taxa were recorded from L. Wamala, with only two haplochromine species Overall, twelve fish taxa were recorded from L. Victoria. Twenty-two haplochromine species were recorded from the lake. The habitats with rocky outcrops and macrophyte cover were found to have the highest number of fish taxa. River Sio had a higher number of fish taxa (17) than R. Nile (7). Results show that some of the fish species that have disappeared from lakes Victoria and Kyoga are present in the satellite lakes and rivers surveyed. Inshore areas with aquatic macrophytes and rocky kabitats were also found to be important refugia for the endangered fish species. Some of the satellite lakes and the selected habitats within the main lakes should therefore be protected for conservation of fish species diversity

Key words: Conservation, introductions, refugia, satellite lakes, extinct

Introduction

Fish species diversity in capture fisheries is very important as it provides choice for consumers and plasticity in employment opportunities. It is also important in the ecological functioning of the aquatic ecosystems. However, human activities such as over-fishing and species introductions have caused rapid reduction in fish species diversity. Loss of fish species diversity is a threat to the food supply, income and health of the people and to the maintenance of ecological functioning in the aquatic ecosystems.

Lakes Victoria and Kyoga had high species diversity with many species in common. Haplochromines were the most abundant group of fishes in these lakes and formed at least 83% of the fish biomass in L. Victoria before the 1980s (Kudhongania & Cordone, 1974). They were important as human food and in evolutionary studies. L. Victoria alone had over 300 haplochromine species, more than 99% of them endemic (Witte et al., 1992a). The original fish fauna had evolved into a trophic diversity that promoted efficient utilization of most of the available energy resources. Tilapiine cichlids and phytoplanktivorous haplochromines were the primary converters, *R. argentea* and several other small fishes preyed mainly on zooplankton while the major invertebrate/benthos feeders were *Clarias* spp, *Schilbe intermedius*, *Synodontis* spp, *Protopterus aethiopicus*, *Labeo victorianus* and several mormyrids (Twongo 1988). The major predator was *Bagrus* *docmac*. Two tilapiine species, *O. esculentus* and *Oreochromis. variabilis*, were the most important commercial species in these lakes. The rivers in the two lake basins had a number of riverine species the commercially important of which was *L. victorianus*.

Stocks of the originally most important commercial species especially *O. esculentus*, *O. variabilis* and *L. victorianus* were depleted by human exploitation during the first half of the 20th century (Graham, 1929). Thereafter the fishery shifted to the smaller originally less preferred species, the haplochromines and *R.. argentea*.

In an effort to sustain the declining fishery of the large species, four exotic tilapiine species *Oreochromis niloticus*, *O. leucostictus*, *Tilapia zillii* and *Tilapia melanopleura* were introduced into lakes Victoria and Kyoga from 1953 onwards. Later, the predatory Nile perch, *Lates niloticus* was introduced into L. Kyoga in 1955 and into L. Victoria towards the end of 1950s, to feed on the haplochromine cichlids and convert them into a larger table fish, and also to develop a sport fishery (Ogutu-Ohwayo, 1990).

The introduced species upset the original ecological balance of the lake and caused changes in species diversity, the fishery and the environment of these lakes. As the stocks of Nile perch increased, fish species diversity, especially of the haplochromines, decreased rapidly. The contribution of haplochromines to fish biomass in the lake decreased from 83% recorded during the 1970s to the early 1980s to less than 1% from the late 1980s onwards (Okaronon et al 1985). About 60% of the haplochromine species are thought to have become extinct from L. Victoria alone (Witte et al 1992). Thereafter, the two introduced species, Nile perch and Nile tilapia dominated the fishery of lakes Victoria and Kyoga. The pelagic cypriuid *R. argentea*, a major prey species for juvenile Nile perch, is the only indigenous fish species of commercial importance. Recent surveys have shown that populations of two zooplanktivores haplochromines *Yissichromis laparogramma* and *Yssichromis fusiformis* are recovering in the offshore waters of L. Victoria (Tumwebaze, 1997).

The disruption and reduction in stocks of the trophically diverse haplochromine community by Nile perch changed the food web of the lakes and this seems to have reduced their overall ecological efficiency. Algal biomass in L. Victoria increased four to five times, phytoplankton production doubled and water transparency decreased (Mugidde, 1993). Depletion of the detritivorous/phytoplanktivorous haplochromines, which previously constituted about 50% of the total haplochromine biomass in L. Victoria, reduced grazing pressure and left much of the algae produced in lake unconsumed. Decay of the excess organic matter depleted the water column of oxygen leading to hypoxic conditions in waters deeper than 40 m especially during periods of stratification. This reduced habitable space for many aerobic organisms and is thought to have forced deepwater haplochromines into shallower waters where they fell easy prey to Nile perch (Hecky, 1993).

Loss of fish species diversity in the Lake Victoria has led to a series of studies directed at identification of faunal refugia. Fish faunal surveys have been carried out in various satellite lakes within the lakes Victoria and Kyoga lake basins, and selected habitats within the main lake to make an inventory of existing fish species, their distribution and relative abundance.

Objectives

The objective of the study was to make an inventory of the fish species in the various satellite lakes and selected habitats in lakes Victoria and Kyoga and assess their value in conservation of fish species diversity.

Study Area, Material and Methods

The study was based on the Napoleon Gulf of Lake Victoria, Lake Kyoga, Kyoga minor lakes, Koki lakes, Nabugabo lakes and Lake Wamala. The areas sampled are shown in Figure. In the Napoleon Gulf sampling was carried out at five stations namely Kiryowa, Kikondo, Kirinya, Rwamafuta and Cliff. Rwamafuta and Kikondo sites are characterised with rocky outcrops, Kiryowa and Kirinya have shorelines with dense macrophyte cover while Cliff site has a steep shoreline without macrophyte cover except for occasional Water hyacinth mats. The Kyoga minor lakes were Nawampasa, Nakuwa, Gigate, Kawi, Lemwa, Nyaguo and Agu. The Nabugabo lakes included lakes Nabugabo, Kayanja and Kayugi. The Koki lakes included lakes Kachera and Mburo. . Some sites along River Nile and River Sio were also sampled. Sampling was carried out between 1997 and 2001.

Fish specimen were obtained from experimental gillnets and basket traps. Three graded fleets of gillnets were used on each lake. Each fleet consisted of 8 panels of mesh sizes 1, 1.5, 2, 2.5, 3, 4, 5,6,7 and 8 inches stretched mesh. The first fleet of nets was set along the shoreline; a second series was set 20 m and a third 200 m away and parallel to the shoreline. Rivers Nile and Sio were also sampled as above.

The nets were set at dusk, left overnight and retrieved the following morning. On retrieval, fish were sorted into taxonomic groups to species level whenever possible and the number and weight of each taxa in each mesh size of net recorded. The fish that could not be identified in the field were preserved in 10% Formalin, labelled with date, habitat and time of capture and transported to laboratory for species identification. Identification of fish to species level was based on Greenwood, 1974 and 1981.

Results

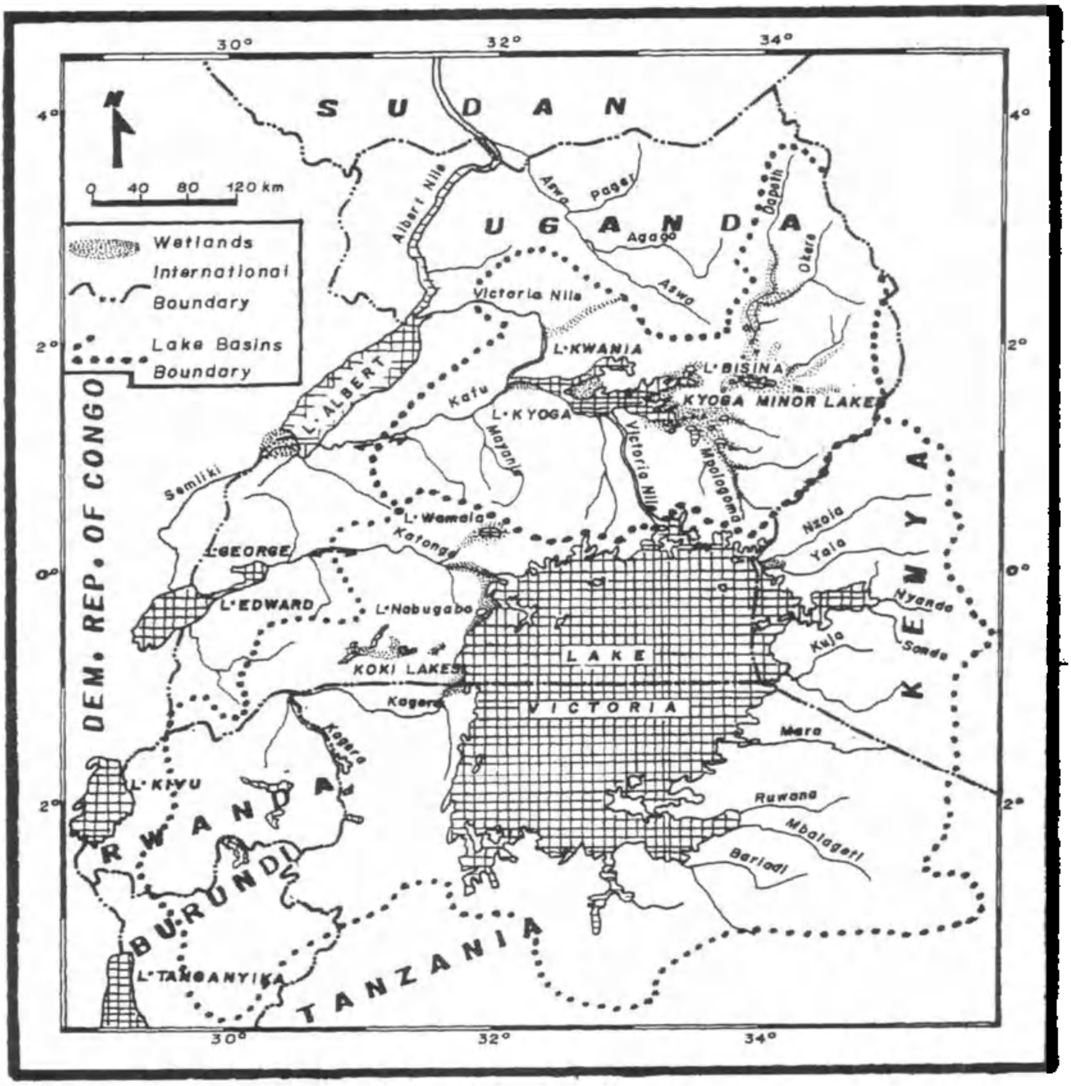
Lake Victoria

Sampling was carried out at five sites namely Kiryowa, Cliff, Kikondo, Kirinya and Rwamafuta. The fish species recorded from Lake Victoria and their relative abundances is shown in Table 1. Overall, twelve fish taxa were recorded. Numerically, Nile perch was the most dominant (42.3%) followed by haplochromines (30.7%), *Oreochromis niloticus* (12.2%), *T.zillii* (8.9%), *Synodontis afrofischeri* (2.3 %) and *Brycinus sadleri* (1.9%). Other species recorded in small numbers included *Mormyrus kannume, Oreochromis leucostictus, Synodontis victoriae, Clarias gariepinus, Oreochromis variabilis*, and *Protopterus aethiopicus*. Fish species distribution varied with species as shown in Figure 2. Generally the highest number of fish was recorded from the inshore fleet followed by the middle and the offshore fleets. The average number of Nile perch, *Synodontis* spp. and *M. kannume* increased from inshore to offshore while that of haplochromines, O.

Table 1. Percent composition, by number, of fish taxa from different pilot zones

Species	L.Victoria (N. Gulf)	Lake Kyoga	Kyoga minor	River Sio	Nabugabo lakes	Koki lakes	Lake Wamala
Lates niloticus	42.3	15.4	0.2	11.0	3.9	0	0
Oreochromis niloticus	12.2	[illegible]	0.3	0.2	7.8	1.1	1.7
Haplochromine	30.7	46	50.7	0.8	61.6	92.8	94.8
Ctenopoma murieri	0	0	0.2	0	0	0	1.1
Afromastacembelus frenatus	0	0	0.1	0.5	0	0	0
Barbus paludinosus	0	0	0.2	0	0	0	0
Schilbe intermedius	0	0.3	0.1	9.2	0.4	0	0
Protopterus aethiopicus	+	0.3	3.5	0.1	0.2	0.2	0.6
Petrocephalus catastoma	0	0.1	5.0	0.6	1.7	0	0
Gnathonemus victoriae	0	14.7	0.3	0.8	0	0	0
Gnathonemus .longibarbis	0	0.1	0.2	0.6	0.1	0	0
Marcusenius nigricans	0	0	0.5	0	0	0	0
Marcusenius grahami	0	0	0	15.5	12.0	0	0
Mormyrus macrocephalus	0	0.6	0	0	0	0	0
Mormyrus kannume	+	+	+	0	0	0	0
Clarias liocephalus	0	0	0.1	0	0.1	0.6	0.1
Clarias gariepinus	+	0.2	0.4	1.2	0.1	0.4	2.1
Brycinus jacksonii	+	0	0	0.1	0	0	0
Bryoinus sadleri	1.9	15	35.3	28.6	4.3	0	0
Laheo victorianus	0	0.1	0	0.8	0	0	0
Barbus altianalis	0	0.1	0.2	0.1	0	0	0
Barbus trispido	0	0	+	0	0	0	0
Barbus sp.	+	0	0.1	0	0	0	0
Synodontis victoriae	+	1.7	0.4	16.1	0	0	0
Synodontis afrofischeri	2.3	0.7	0.7	13.3	1.0	0	0
Oreochromis esculentus	0	0	0.3	0	2.7	3.7	0
Oreochromis leucostictus	+	1.0	0.7	0	0.4	1.1	0.5
Oreochromis variabllis	+	0	0.1	0	0	0	0
Tilapia zillii	8.9	1.1	0.3	0	1.2	+	0.02
Barbus kersteni	0	0	0	0	2.4	0	0
Oreochromis rendalii	0	0	0	0	0.1	0	0
Total number of species	**12**	**18**	**25**	**17**	**17**	**8**	**8**

Figure 1. A map of Uganda showing the Victoria and Kyoga lake basins



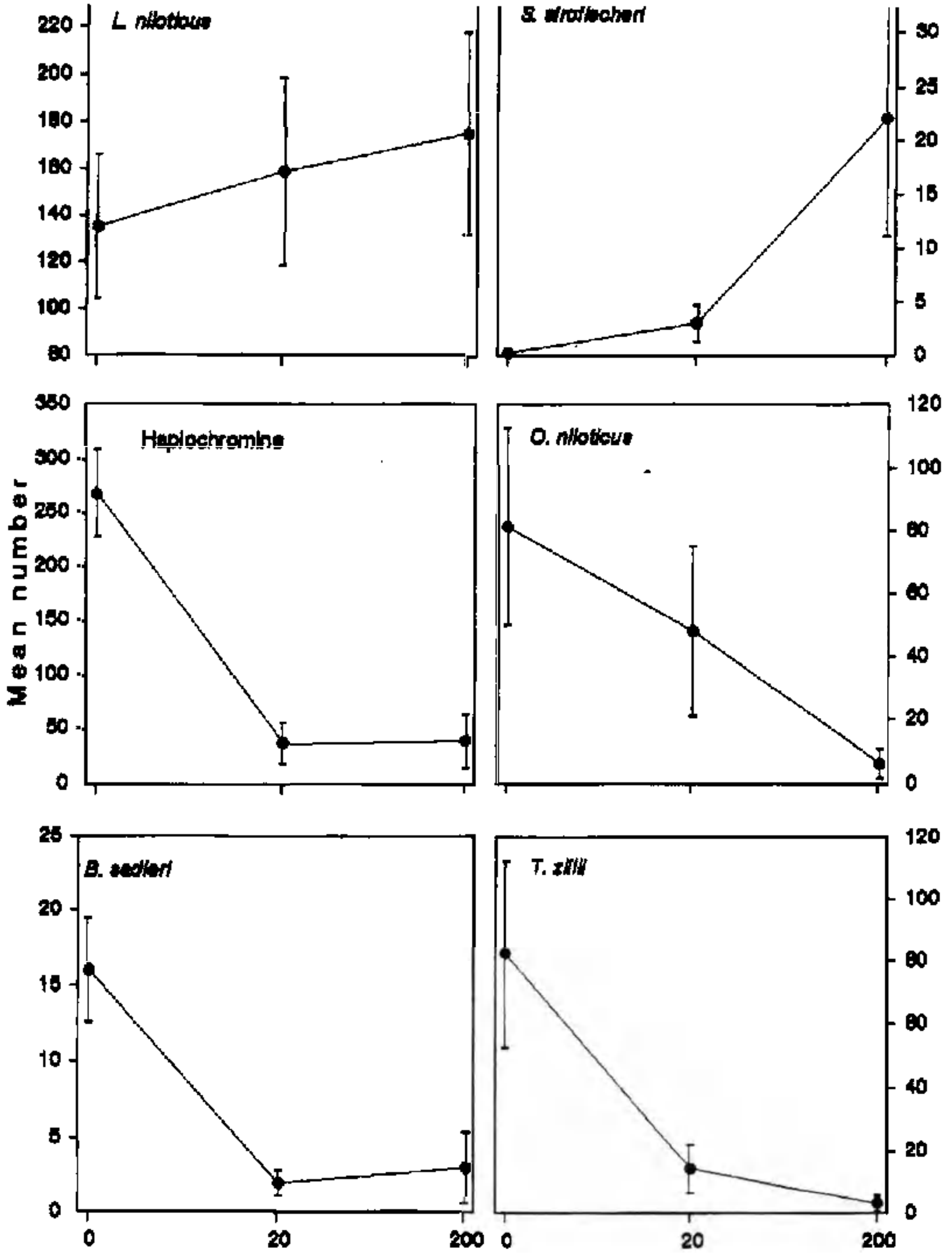
niloticus, T. zillii, B. sadleri, O.leucostictus, C. gariepinus, and *P. aethiopicus* decreased from inshore to offshore. *O. variabilis* was recorded only from the inshore nets. Number of fish species was highest at Rwamafuta (12) and Kikondo (12) each, followed by Kiryowa (11), Kirinya (10) and Cliff (8). Twenty-two haplochromine species were recorded from the five stations.

Lake Kyoga

Eighteen taxa species were recorded and these included haplochromines, *L. niloticus, Brycinus sadleri, Gnathonemus victoriae, O. niloticus, Synodontis victoriae, Synodontis afrofischeri, Mormyrus macrocephalus. T. zillii, O. leucostictus, Schilbe intermedius, Protopterus aethiopicus, C. gariepinus. Labeo victorianus, Gnathonemus longibarbis, Barbus altianalis, Petrocephalus catastoma*, and *M. kannume*. The highest number of species occurred in inshore (13) followed by offshore (11) and middle fleets (8). Fourteen haplochromine species were recorded as shown in Table 1. Their distribution varied with species but the highest number occurred inshore.

Kyoga Minor lakes

Overall twenty-seven fish species were recorded from Kyoga minor. Fish species composition and relative abundance of fish species recorded from the different lakes is shown in Table 2. These included haplochromines *B. sadleri, T.zillii, O. esculentus, S. victoriae, S. afrofischeri, O. variabilis, Afromastacembalus frenatus. Ctenopoma murieri, Barbus paludinosus, Barbus altianalis, S. intermedius, Barbus trispidopleura, Barbus* sp., *P. catastoma, C.*



Distance in metres from the shore

Figure 2. Overall distribution of dominant fish taxa in the Napoleon Gulf

Table 2. Percent composition, by number, of fish taxa from the Kyoga minor lakes

Species	Nawampasa	Nakuwa	Lemwa	Kawi	Gigate	Nyaguo	Agu
L.niloticus	0	12.8	0	0	0	0	0
O. niloticus	0.1	3.7	0.3	0.1	0.3	0	0
Haplochromines	67.5	11.0	89.3	69.4	67.3	5.9	80.8
C.murieri	0	0	1.0	0	0	0	7.1
A. frenatus	0	0	0	0	0	0.1	0
B.palludinosus	0	0	0	0	0	0.7	0
S.intermedius	0	3.7	0	0	0	0	0
P. aethiopicus	0.3	2.7	0	29.3	0.03	0.1	0.5
P.catastoma	0	0	0	0	0	21.4	1.0
G.victoriae	0	1.8	0	0	0	1.1	0
G.longibarbis	0	0	0	0	0	0.5	4.5
M.nigricans	0	0	0	0	0	2.1	1.0
M.grahami	0	0	0	0	0	0	0
M.macrocephalus	0	0	0	0	0	0.1	0
M.kannume	0	0	0	0	0	0	0
C.liocephalus	0	4.6	0	0	0	0	0
C.gariepinus	0.5	0.9	2.9	0.4	0.3	0.1	0
B.sadleri	26.0	0	0	0	31.1	67.4	0
B.altianalis	0	12.8	0	0	0	0	0
B.trispidopleura	0	0	0.3	0	0	0	0
Barbus sp.	0	0	2.3	0.1	0	0	0
S.victoriae	0.8	14.7	1.0	0	0	0.1	0
S.afrofischeri	0.7	32.1	0.3	0.2	0.03	0	1.0
O.esculentus	1.4	0	0.3	0.2	0	0.4	0
O.leucostictus	0.3	1.8	2.3	0.4	0.8	0.1	0.5
O.variabilis	0.7	0	0	0	0	0	0
T.zillii	1.5	0	0	0	0	0	3.5
Total umber of species	**11**	**12**	**10**	**8**	**7**	**14**	**9**

gariepinus, M. grahami, C. liocephalus, G. victoriae, G. longibarbis, O. leucostictus, P. aethiopicus, Mormyrus kannume, Mormyrus macrocephalus and O. niloticus. Fish species distribution varied within each lake but generally the inshore habitats with macrophyte cover had the highest fish species *diversity*.

Nabugabo lakes

Three lakes were sampled namely, Nabugabo, Kayanja, and Kayugi. Overall thirteen fish taxa were recorded from L. Nabugabo and they included haplochromines (48.8%), *B. sadleri* (11.3%), *Barbus* spp (0.4%)., *G. longibarbis* (0.2%), *L. niloticus* (11.0%), *M. grahami* (0.1%), *O. rendalii* (0.3%), *O. leucosticus* (0.9%), *O. niloticus* (22.2%), *P. aethiopicus* (0.1%), *S. intermedius* (1.0%), *S. afrofischeri* (2.8%) and *T. zillii* (0.9%). Four species of haplochromine cichlids were recorded from L. Nabugabo *and they included Astatotilapia velifer, Gaurochromis simpsoni, Paralabidochromis beadlei* and *A. alluaudi*.

Eleven fish taxa were recorded from L. Kayanja namely; *haplochromines* (58.9%), *B. kersterni* (4.2%), *B. sadleri* (0.3%), *C. gariepinus* (0.3%), *C. liocephalus* (0.1%), *G. victoriae* (5.3%), *M. grahami* (23.7%), *O. esculentus* (5.1%), *O. leucosticus* (0.2%), *P. aethiopicus* (0.2%), and *T. zillii* (1.7%). The haplochromine species included *A. alluaudi, A. nubila, Aststotilapia* ssp. and *Prognathochromis venator*.

From Lake Kayugi seven fish taxa were recorded and they included haplochromines (82.2%), *B. sadleri* (1.3%), *B. kersterni* (0.8%), *G. victoriae* (4.9%), *O. esculentus* (1.1%), *P. catostoma* (9.7%) and *P. aethiopicus* (0.2%). The haplochromine cichlids inclueded *A. velifer, A. nubila, G. simpsoni, A. alluadi* and *P. venator.* Overall seventeen fish taxa were recorded from the Nabugabo lakes as shown in Table 1.

Koki Lakes

Experimental fishing was carried out in lakes Mburo and Kachera. From Lake Mburo 6 fish taxa were recorded. These were haplochromines (95.5%), O. esculentus (3.2%), *O. niloticus* (0.8%), *O. leucostictus* (0.3%), *C. gariepinus* (0.1%), and *P. aethiopicus* (0.1%). *The haplochromine cichlids belonged to four species namely Astatotilapia aeneocolor, Astatotilapia nubila, Astatoreochromis alluaudi* and *Harpagochromis squamipinnis. Generally, the inshore sites had the highest number of fish although distribution varied with individual species. Numbers of O. esculentus, C. gariepinus* and *P. aethiopicus were highest in the inshore fleets while O. niloticus was most abundant in the middle fleets. Among the haplochromines, H. squamipinnis* and *A. aeneocolor were most abundant in the offshore fleets while A. alluaudi and A. nubila were most abundant in the inshore fleet.*

Eight fish taxa were recorded from Lake Kachera. The most abundant were haplochromines (90.6%), *O. esculentus (4.2%), O. leucosticus (1.7%), O. niloticus (1.4%), C. liocephalus (1.1%), C. gariepinus (0.6%). P. aethiopicus (0.4%) and T. zillii. The haplochromine cichlids included* H. squamipinnis, A.aeneocolor, A. alluaudi *and* A. nubile. *Fish species distribution was as for Lake Mburo*

Lake Wamala

Overall, 9 fish taxa were recorded from L. Wamala as shown in Table 1. Numerically the most abundant species was *O. niloticus, haplochromines, O. leucostictus, C. gariepinus, Ctenopoma murueri* , *C. liocephalus, P. aethiopicus, C. carsoni, T. zillii. C. gariepinus* was most abundant in the offshore while the other species occurred mostly in the inshore fleet. There were two species of haplochromines namely *A. nubila* and *Pseudocrenilabrus multicolor.*

River Sio

Seventeen fish taxa were recorded and they included *B. sadleri* (28.6%), *M. grahami* (15.5%), *S. victoriae* ((16.1%), *S. afrofischeri* (13.5%), *L. niloticus* (11.0%), Haplochromines (0.8%), *C. gariepinus* (1.2%), *P. catastoma* (0.6%), *G. longibarbis* (0.6%), *S. intermedius* (9.2%), *L. victorianus* (0.8%), *G. victoriae* (0.8%), *O. niloticus* (0.2%), *Brycinus jacksonii* (0.1%), *B. altianalis* (0.1%), *A. frenatus* (0.3%) and *P. aethiopicus* (0.1%). The nearshore habitat had the highest number of species (15) followed by the middlefleet (10) and the offshore fleet (8).

River Nile

Seven fish taxa were recorded and they included, in order of abundance, Mormyrus kannume (37.9%), L. niloticus (23.7%), haplochromines (22.0%), Barbus altianalis (7.3%), B.sadleri (3.1%), O. niloticus (2.1%), O. variabilis (1.8%), M. macrocephalus (0.6%), Bagrus *docmac (0.6%), T. zillii (0.5%) and crabs (0.5%).*

Discussion

Fish species diversity decreased with increasing distance from the shoreline, which at all the sites sampled, was fringed with aquatic macrophytes. Sites that are sites, both of which are characterized with rocky shorelines, notably Rwamafuta and Kikondo had high species diversity. Fish species diversity in the satellite lakes and rivers was also found to be highest in habitats with submerged and fringing macrophytes. Studies carried out in Lake Victoria in the early 1990s showed that marginal swamps and rocky reefs were important refugia for indigenous species in Lake Victoria (Kaufman and Ochumba, 1993; Namulemo, 1997). Ogutu-Ohwayo (1993) noted that many surviving species, especially haplochromines, in Lake Nabugabo were confined to macrophytes along the lake margin.

Inshore areas with aquatic macrophytes may serve as both structural and in some cases low-oxygen refugia for prey species from Nile perch. Chapman et al (1995) demonstrated that some of the cichlids from Lake Victoria could tolerate extremely low levels of oxygen, which may permit these fishes to use structural inshore habitats as refugia.

In the present study, the value of structural refugia has also been observed in satellite lakes with Nile perch. For instance in lakes Nabugabo and Nakuwa where Nile perch was introduced, most of the haplochromine cichlids live among submerged macrophytes especially water lilies where they are probably able to evade predation by Nile perch. Submerged and fringing macrophytes also act as barriers to the spread of the Nile perch since the species cannot survive under low oxygen conditions. For instance, L. Nawampasa is separated from L. Kyoga, where Nile perch occurs, by dense macrophytes that act as a barrier to the entry of Nile perch into the lake.

It was noted in the Mwanza Gulf of Lake Victoria that it is the rock dwelling fish species that have been least affected by Nile perch predation (Witte et al, *1992).* This suggests that rocky areas can serve as refugia for some haplochromines and other rock dwelling fish species.

Conclusion and recommendations

The information gathered so far indicates that marginal macrophytes and rocky habitats provide both structural and physiological refugia for the endangered native fish species in L. Victoria and may be valuable in conservation of fish species diversity in the lake. It has also been observed that the satellite lakes of the Victoria and Kyoga lake basins provide a sanctuary for *O. esculentus* and many haplochromine species which are believed to be extinct from L. Victoria. Some of these lakes should therefore be protected for conservation of fish species diversity and as a source of brood stock for fish farming. Rivers Sio and Nile were also found to be rich in fish species diversity and important sources of *L.victorianus* as brood stock in fish farming. These rivers should also be protected for conservation of fish species diversity. Some of the measures to conserve fish species diversity should include

- Avoid clearing the papyrus swamps and marginal vegetation along the lakes in order to stop the spread of exotic fish species and also to avoid other anthropogenic impacts on the lakes
- Declare some satellite lakes and special habitats within the main lake Victoria as conservation areas and set up marine parks
- Avoid use of destructive fishing gears especially beach seines which are
- operated along shorelines which are important breeding and nursery grounds for most of the fish species

References

Graham, M., 1929. The Victoria Nyanza, and its fisheries.

A report on the fishery survey of Lake Victoria. (1927-29). Crown Agents Colonies, London.

Hecky, R.E.. 1993. Peter Kilham Memorial Lecture. The eutrophication of Lake Victoria. Verh. Int. Verein. Limnol. 25: 39-48

Kudhongania, A.W. & Cordone, A.J., 1974. Bathiospatiool distribution pattern and biomass estimate of the major demersal fishes in Lake Victoria. Afr. J. Trip. Hydrobiol. Fish. 3: 15-31

Mugidde, R., 1993. The increase in phytoplankton production and biomass in Lake Victoria (Uganda). Verh. Int. Verein. Limnol. 25: 846-849

Namulemo, G. 1997. Distribution, relative abundance and food of the surviving haplochromine cichlids in the littoral areas of Napoleon Gulf (Lake Victoria). Msc. Thesis Makerere University. Kampala. 89pp

Ogutu-Ohwayo, R., 1990. The decline of native fish species diversity in lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile perch, Lates niloticus, and the Nile tilapia, Oreochromis niloticus. Env. Biol. Fish. 27: 81-96

Okaronon, J. O., Acere, T.O & Ocenodongo, D.L., 1985. The current state of the fisheries in the northern portion of Lake Victoria. pp. 89-98.1:CIFA. Report of the third session of the sub-committee for the development and management of the fisheries of Lake Victoria. 4-5 October 1984. Jinja, Uganda. FAO Fish. Rep. 335. FAO, Rome

Tumwebaze, R., 1997. Application of hydroacoustics in fish stock assessment of Lake Victoria. MPhil Thesis. Department of Fisheries & Marine Biology. University of Bergen, Norway. 134 pp.

Twongo, T., 1998. Recent trends in the Fisheries of Lake Kioga. pp. 140-151. 1:CIFA. Report of the third session of the sub-committee for the development and management of the fisheries of Lake Victoria. 4-5 October 1984. Jinja, Uganda. FAO Fish. Rep. 335. FAO. Rome

Witte, F., Goldschmidt, T., Goudswaard, P.C., Ligtvoet, W., Oijen, M.J.P. van & Wanink, T.H., 1992a. Species extinction and concomittant ecological changes in Lake Victoria. Neth. J. Zool. 42: 214-232

Witte, F. Goldschmidt, T., Goudswaard, P.C., Ligtvoet, W., Oijen, M.J.P. van & Wanink, J.H., 1992b. The destruction of an endemic species flock: quantitative data on the decline of the haplochromine cichlids of Lake Victoria. Env. Biol. Fish. 34: 1-28