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Proliferation, impacts and control of water hyacinth in Uganda

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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

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)

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

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.

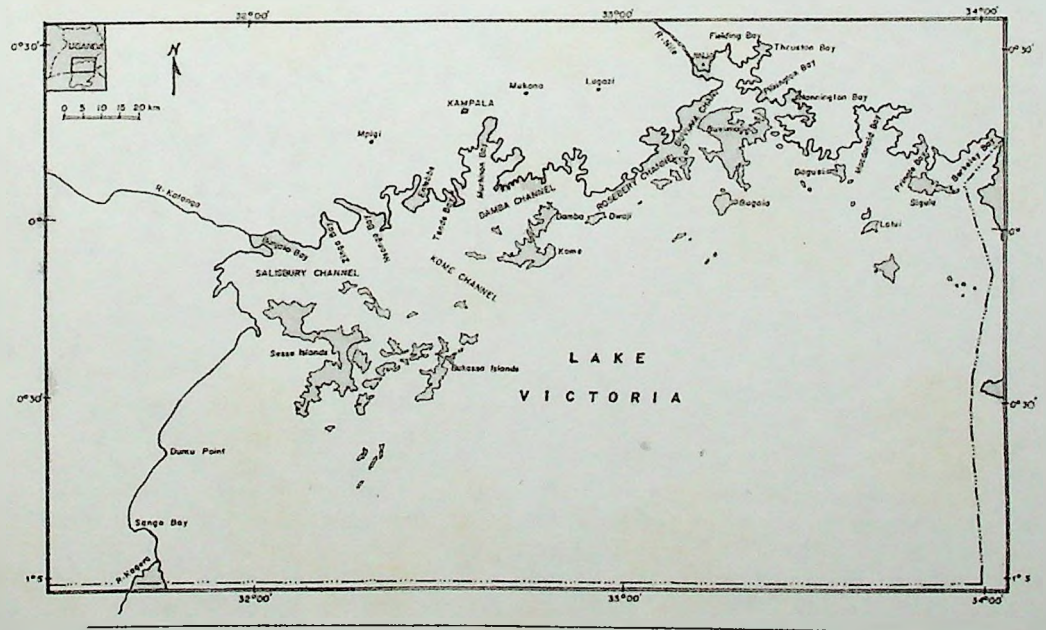
Impacts of water hyacinth proliferation

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.

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