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The Potential for further proliferation of Water Hyacinth in Lakes Victoria, Kyoga and Kwania and some urgent aspects for research[1]

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ABSTRACT

Shore environments of lakes Victoria and Kyoga with potential for the establishment and proliferation of water hyacinth were identified. They are characterised by: (i) shelter from violent off-shore and along-the-shore wind and wave action (ii) flat or gentle slope under relatively shallow water, and (iii) a muddy bottom rich in organic matter. Such environments are strongly associated with emergent macrophytes of papyrus, *Vossia* sp and, at times *Typha* sp where *Pistia stratiotes*, species of *Ceratophyllum, Myriophylum* and *Nymphaea* also occur. In Lake Kyoga association with *Vossia* sp facilitated establishment of water hyacinth even along wind-swept shores and promoted extension of mats of the two machrophytes into the open lake. Urgent research on water hyacinth is proposed in the areas of nutrient relations, weed biology and on its impact on the biodiversity resource, with particular emphasis on the fishery component. Findings from the research could facilitate formulation of weed control options and alternative resource management strategies. A regional approach to address the water hyacinth menace is highly recommended.

INTRODUCTION

In its native range in tropical South America, water hyacinth *Eichhornia crassipes* (Mart) Solms occurs virtually harmlessly in seasonally inundated environments rather than in permanent water bodies like the large lakes of East Africa where the weed has appeared. Admirers of its beautiful flower have translocated water hyacinth almost world-wide, and in the tropical and subtropical environments, the weed has reproduced prolifically and spread rapidly to become one of the most notorious freshwater weeds. In Uganda, where water hyacinth was first reported in Lake Kyoga in 1988 and in Lake Victoria in 1989, weed distribution around both lakes is almost complete (TWONGO, 1991a; THOMPSON, 1991). There is therefore growing concern about its proliferation potential from two perspectives. First, the rapidly accumulating biomass would negatively impact the lake environment for fisheries production, maintenance of aquatic biodiversity, water transportation and for potable water supply. This trend is already apparent on Lake Kyoga; and large quantities of water hyacinth biomass on Lake Victoria could also eventually become a constraint on hydro-electric power generation at the Owen Falls plant, Jinja. Secondly, the current trend towards eutrophication of lakes Victoria and Kyoga is likely to sustain increased productivity of the weed.

In spite of the above concern and of the heavy dependence by the lakeside communities in East Africa on lake resources especially water and fish, and, although hydro-electricity and commercial fisheries are regional economic assets, the potential danger posed by the proliferation of water hyacinth to lake resources around Lake Victoria is not yet appreciated. This paper is firstly, to try and illustrate the impending danger to lake resources availability due to increased infestation by the water weed. In this connection, the potential for further proliferation of water hyacinth on lakes Victoria and Kyoga is highlighted. Secondly, although the water hyacinth has been in the lower

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Pangani in Tanzania, and in the Sudan since the 1950s, scientific information about it in this region is highly limited. Some urgent aspects for research to improve knowledge on the biology and ecology of water hyacinth and on its environmental impacts on various lake resources have been identified. It is expected that the results of studies made on lakes Victoria and Kyoga would lead to options for control of water hyacinth and for lake resources management in the presence of the noxious weed.

METHODS OF STUDY

Surveys were made in a canoe powered by 25 hp outboard engine along the entire shoreline of lakes Kyoga and Victoria—Uganda portion, including the major islands. Lake Kyoga where the weed was reported earlier (TWONGO, 1991a) was surveyed thrice between 1988 and 1991 while Lake Victoria was surveyed once from 27 December 1991 to 17 January 1992. During the survey the shoreline was carefully inspected and the following environmental features were evaluated in relation to presence of major infestations of water hyacinth:

1. slope of the shore landward (by ocular assessment) and lakeward (based on depth soundings along transects);
2. lake bottom type (whether rocky, firm soil or muddy), based on Ponar grab samples;
3. presence of emergent, floating and/or submerged shore vegetation;
4. overall shelter situation: whether in a bay or along open shoreline, exposed to or on the lee of prevailing winds.

Some physical and chemical parameters (temperature, pH, conductivity, dissolved oxygen and redox potential) were measured in various bays on Lake Victoria using a Hydrolab Surveyor II to compare the water environment in hyacinth mats with that off the edge of the water weed. The parameters were measured about 10m away from the edge of the mat and only five metres inside it because larger water hyacinth mats were not common. Average dissolved oxygen level was obtained from measurements taken at depth intervals of 50cm.

RESULTS

Candidate habitats

The survey of the shores of Lake Kyoga and Lake Victoria in Uganda revealed presence of establishing water hyacinth growing in habitats with the following shoreline environmental features:

1. shelter from violent off-shore and along-the-shore wind and wave action;
2. flat or gently sloping shores that are relatively shallow (rarely deeper than five meters);
3. a soft muddy bottom rich in organic matter.

Along the shores of Lakes Victoria and Kyoga, sites with the above characteristics supported an emergent macrophyte flora of papyrus - *Cyperus papyrus* with patches of *Vossia sp.* A strong association was, therefore, established between shore environments supporting the growth of *C. papyrus* or *Vossia sp.* and the presence of water hyacinth. This association which was established early during the surveys, made it easier to locate water hyacinth infestations since the above emergent macrophytes could be seen from a long way off especially with the aid of binoculars. In Lake Victoria, stands of *Typha sp.* were often scattered among the papyrus or formed a background to it, especially along the north eastern shores of the lake but became rare towards the west. *Typha sp.* tended to grow on firmer clay soils. Shore zones with the features listed above almost always carried one or several of the following euhydrophytes in both lakes: Nile lettuce *Pistia stratiotes*, *Ceratophyllum demersum*, *Myriophylum sp.*, and *Nymphaea sp.* while *Potamogeton spp.* occurred at a few sites.

Spatial Spread

Water hyacinth occurred in almost all habitats with environmental features already identified as favouring weed establishment. In Lake Victoria (Fig. 1) environments favouring establishment of water hyacinth were usually located at the tips of small bays and inlets within large bays such as Macdonald and Murchison. Water hyacinth occurred in large well established mats already breaking off to supply new invasion units. The water weed was also frequently found as newly established mats growing luxuriantly or in form of propagules consisting of one or several plants cryptically perched among emergent macrophytes. The small plants were clearly the product of vegetative propagation from pieces of stolon broken up most probably by the waves.

Water hyacinth mats were also found at unexpected locations such as exposed shores with hard rocky or sandy bottom not identified during the surveys as suitable for weed establishment and luxuriant growth. Such mats usually showed poor growth

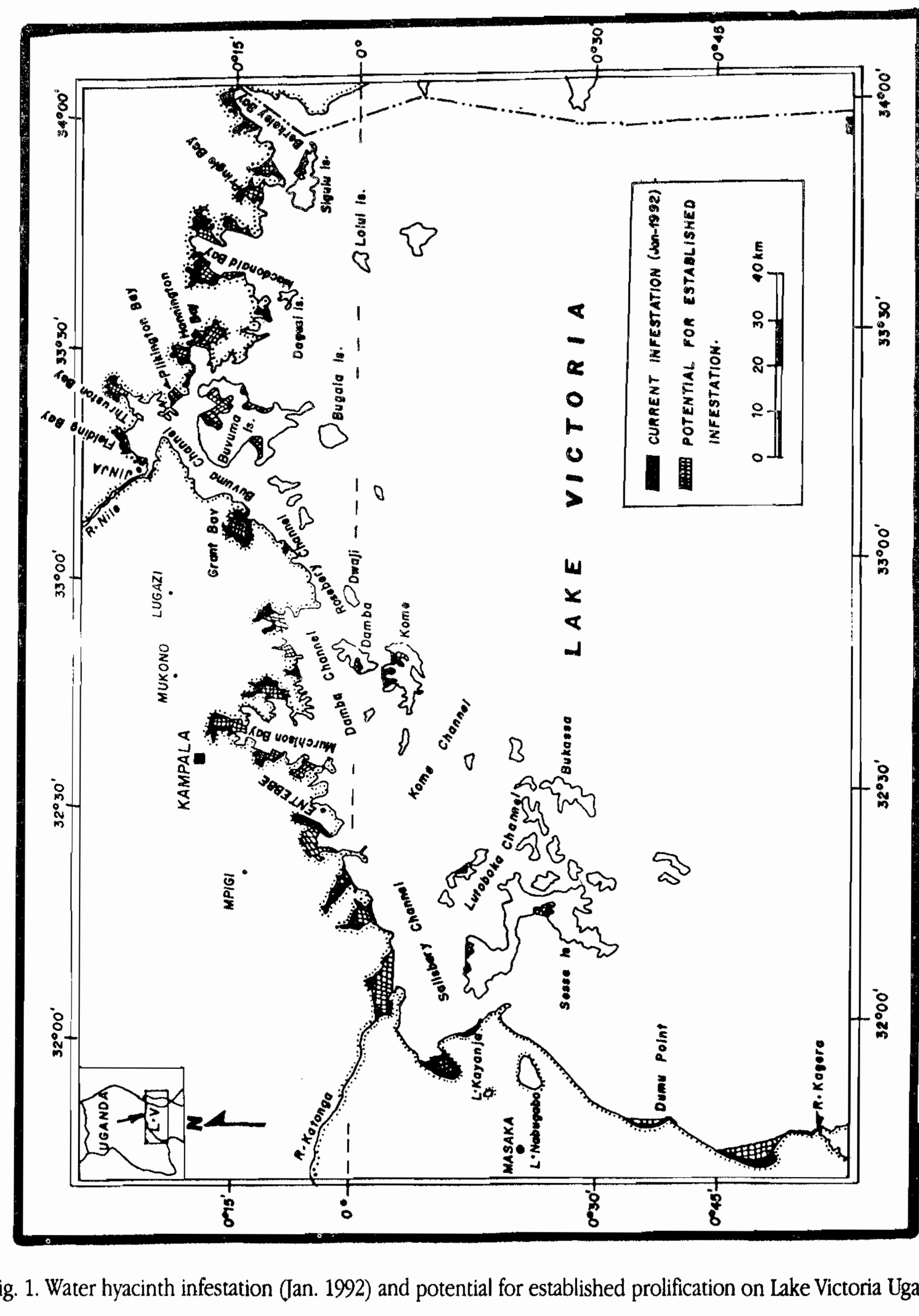

Fig. 1. Water hyacinth infestation (Jan. 1992) and potential for established prolification on Lake Victoria Uganda

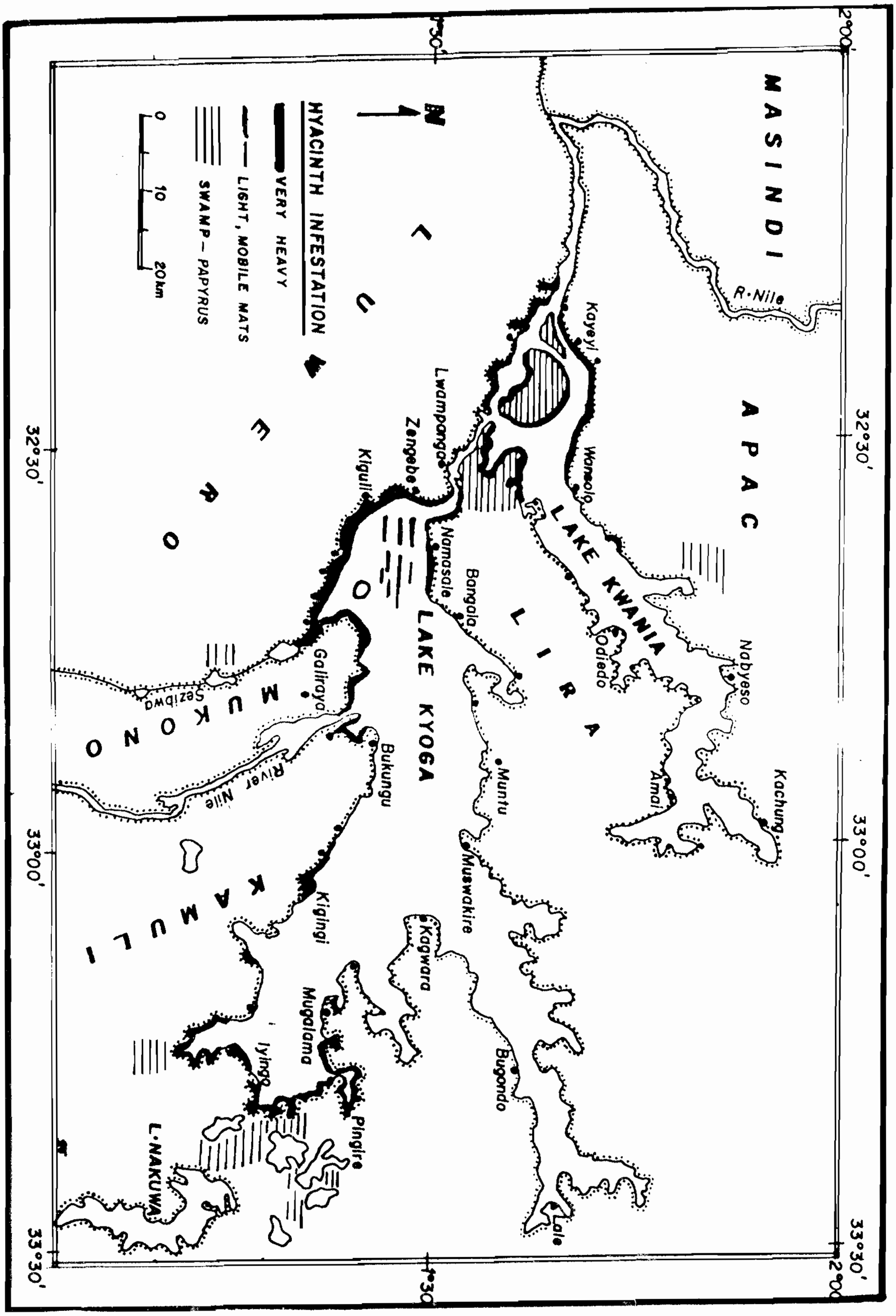

Fig. 2: Water hyacinth infestation on lakes Kyoga and Kwania - Nov. 1991 (From TWONGO, 1991a)

and were likely to have been stranded at the locations by onshore winds.

They would probably drift off as soon as the winds ceased to blow or changed direction. This type of "migratory" hyacinth was a constant problem at landing sites in heavily infested bays.

In Lake Kyoga (Fig.2) water hyacinth had already spread to cover most potential sites for infestation by the weed along the shore, as identified in this study. Such sites were generally confined to the eastern papyrus swamp border of the lake plus a bit of adjoining north and south shore; to the entire western half of the south shore from Bukungu fish landing near the Nile "delta"; and to a portion of the north western shore. In many of the above sites, the association between hyacinth and *Vossia* sp. facilitated extensive colonisation of the open lake by firm "fields" of the associated macrophytes. On the other hand, most of the north shore and the eastern part of the south shore of Lake Kyoga were unlikely to harbour established mats of the weed because they are generally sandy or of a firm bottom, under relatively deeper waters of about three metres or more.

Only the most southerly portion of Lake Kwania, was suitable for colonization by water hyacinth. This area was in fact already infested with the weed (Fig. 2). The zone where Lake Kwania joins River Nile as it emerges from Lake Kyoga is very shallow and is extensively covered with papyrus islands which were already fringed by the water weed. It is probable that the fringing hyacinth could expand and choke the passages among the papyrus islands. Closure of these passages would lock up very important fishing grounds for Nile tilapia, *Oreochromis niloticus,* and African lung fish, *Protopterus aethiopicus,* among the floating papyrus islands. The rest of the long Lake Kwania has wave-swept-shores with firm bottom. Water hyacinth may not establish along such shores to form firm extensive mats. However, the northern tip of the lake has shallow sheltered shores that might encourage colonization by the weed. Large mats from the southern portion could, of course, be blown up and down the lake by the strong winds often encountered on this lake.

Hyacinth-macrophyte associations

It was noted that along the shores of the small narrow and generally shallow Lake Kyoga (average depth 3m), sheltered environments that supported establishment of water hyacinth were not confined to bays and inlets as was basically the case in Lake Victoria. Straight shores fringed by emergent macrophytes notably *C. papyrus, Vossia* sp. and at times, by *Cyperus* spp. which provide shelter from off-shore wind supported established weed growth (Fig.2). Secondly, a peculiar association comprised by water hyacinth, *Vossia* sp and often *Cyperus* spp facilitated rapid extension of stable mats of the associated macrophytes towards the open lake even along exposed shores. This association plus shallow water of two meters or less were largely responsible for the rapid establishment of water hyacinth along straight shores such as occur along the south of western Lake Kyoga in Luwero District.

Water quality

Various water quality parameters at several water hyacinth infested sites on Lake Victoria are given in Table 1.

Table 1. **Water Quality Parameters at Hyacinth Infested Sites on Lake Victoria - Uganda**

	Inside water hyacinth mat								10 m off water hyacinth mat						
Location	Time am	Water depth m	Secchi m	Temp °C	pH	DO mg l^{-1}	Cond. uS/cm	ORP	Water Depth m	Secchi m	Temp °C	pH	Do mg l^{-1}	Cond uS/cm^{-1}	ORP
Hannington Bay	7.52	1.0	1.0	25.6	7.72	0.87	110	0.262	2.0	0.8	25.7	9.13	7.55	106.0	0.204
MacDonald Bay	8.20	1.0	1.0	27.2	7.99	4.19	110	0.211	1.0	1.0	27.0	8.50	7.18	107.0	0.161
Zinga Bay	8.20	1.0	1.0	23.6	8.69	5.55	104	0.217	1.5	1.1	23.9	9.64	8.10	105.0	0.135

DISCUSSION

Potential for further proliferation

Results of the surveys established a strong linkage between water hyacinth and the sheltered bays and inlets which are so characteristic of the shores of Lake Victoria in Uganda. The association of these sheltered bays with emergent wetland macrophytes dominated by papyrus was a prominent indicator of the potential zones for water hyacinth proliferation. In view of the above linkage, the extensive cover of papyrus along the shores of lakes and rivers in Uganda, is a clear manifestation of the huge potential for further proliferation of water hyacinth in the country.

Observations on Lakes Kyoga and Kwania indicated that most sheltered bays suitable for established growth of water hyacinth had been colonised by the weed. It appeared, therefore, that the potential for further infestation of lakes Kyoga and Kwania by water hyacinth was becoming limited to expansion into the open lake either through stable mat formation in association with emergent macrophytes or when large migrant mats were blown about the lake by wind. Environments suitable for rapid hyacinth proliferation under stable conditions would, thereby, continue to export the weed to the open lake. In view of the generally shallow and nutrient rich diurnally mixed environments of Lake Kyoga and Lake Kwania (average depth 3.5m) which would probably nourish water hyacinth proliferation off shore, the overall potential menace due to the negative impacts of the water weed to the multipurpose uses of these lakes is significant.

ASPECTS FOR RESEARCH

Influence of nutrients

Detailed literature on various aspects of water hyacinth growth such as nutrient requirements, growth rates and impact on nutrient dynamics in a lake environment appear to be limited. This information is essential for lakes Victoria and Kyoga in order to predict more precisely factors like potential distribution and proliferation of the water weed, and its impact on the nutrient status of these lakes. For example, the observed inability for water hyacinth to grow well and form healthy mats on sandy and clayey shores of lakes Victoria and Kyoga, even under shelter from wind, indicates inadequate nourishment for proper growth. On the other hand, luxuriant weed growth and active proliferation over muddy substrate particularly in relatively shallow water environments suggests several possible influences. First the muddy substrate is probably rich in nutrients essential for the growth of water hyacinth. Secondly, it would appear that under shallow conditions the muddy substrate replenishes nutrients in the water column as they are used up and hence these sustain rapid weed growth.

The second observation above is of considerable interest in view of the distribution of nitrogen ($N\text{-}No_3$), phosphorus ($P\text{-}PO_4$) and silica ($Si\text{-}Si0_2$) in lakes Victoria and Kyoga where concentrations of these nutrients are generally higher near the mud surface and lower in the upper photosynthetic zone (HECKY and BUGENYI, 1992). In order to sustain the high growth rate of water hyacinth, constant replenishment of the essential nutrients would be vital. Hence establishment of water hyacinth in sheltered shallow and muddy environments described above probably relates to the rich organic material often found at such lake bottoms. Research in nutrient dynamics in these environment would clarify the possible role of fungal, microbial and invertebrate biota on the release and cycling of nutrients from organic sediments. It is probable that water hyacinth proliferation benefits from such nutrient sources.

The decline in fish species diversity of lakes Victoria and Kyoga (KUDHONGANIA et al.1991) greatly affected the haplochromine taxon which included major algal grazers. This reduction in the grazing pressure on phytoplankton, combined with an apparent increase in nutrient loading of the lakes from the catchment appear to have contributed to a two to ten fold increase in algal biomass over that reported three decades ago (HECKY and BUGENYI, 1992). The overall accumulation of nutrients has led to conditions of enhanced eutrophication in the two lakes which probably enhances the potential for water hyacinth proliferation.

Water Hyacinth Biology

Several aspects of water hyacinth biology require urgent research in order to understand the growth and propagation patterns of this prolific and luxuriant water weed in Lake Victoria and Kyoga. They include study of the different size forms of the weed - factors controlling their appearance and transformation; of growth rates of individual plants and rates of biomass accumulation; and of reproductive strategies, factors influencing seed formation and viability in the new environments. The following may guide formulation of the research:

(i) Observations during surveys of water hyacinth on lakes Victoria and Kyoga indicated presence of basically two size forms of the weed namely the dwarf seemingly young plants with bulbous petioles and the large plants whose aerial parts may grow up to over one metre in very favourable environments (THOMPSON, 1991). On Lake Victoria the dwarf forms were often found at newly colonized sites and closer examination of these small plants revealed that they were products of vegetative propagation from pieces of stolon probably broken up by wave action. However, the notion of their being young plants was dispelled when a large number of them were found flowering on apparently newly established mats. In Lake Kyoga, on the other hand, dwarf water hyacinth, often in flower, was found in what appeared to be stressful environments, for instance on sandy shores where the plants were not growing luxuriantly.

(ii) Knowledge on the growth patterns and rates of individual plants and matted hyacinth in different environmental conditions is likely to facilitate understanding of hyacinth infestation and proliferation potential in aquatic systems. Growth studies could be made together with studies on the influence of nutrients on water hyacinth biology.

(iii) The vegetative mode of reproduction in water hyacinth is a simple method of horizontal stolon formation by plants followed by development of daughter plants at the end of each stolon. However, the factors that trigger flowering and seed formation should be researched as well as the viability of the seed. In native South America the seeds of this weed are said to germinate after inundation following a period when waterways are dry. It would be interesting to discover under what circumstances the hyacinth seeds in lakes Victoria and Kyoga would germinate and grow into seedlings. This information is indeed vital when considering hyacinth control.

Impact on aquatic resources

The impact of a fresh invasion of a "field" of water hyacinth one hectare in area on the resources of an aquatic ecosystem may be difficult to visualise without some experience with the water weed. However, measurements of various limnological parameters taken during the survey in bays infested with water hyacinth on Lake Victoria (Table 1) illustrate some of the expected impacts. For instance, a comparison of dissolved oxygen (DO) measured five metres inside established weed mats and 10m away from the mat edge shows marked differences. The striking DO differential of 0.87mg at a site in a calm sub-bay of Hannington Bay at 07.52 hours local time (Table 1) reflected the combined effects of water hyacinth respiration, decay processes of the dead parts of the weed and the reduced exchange at the water-air interface due to close weed cover. The pH was also always lower while Secchi disc transparency equalled the water depth under the mats. The above results, suggest much more drastic reductions in dissolved oxygen, plankton biomass and possibly pH farther into the weed mat.

The higher Secchi disc transparency inside the mat as compared to that only 10m off the mat edge indicates a paucity of phytoplankton which in turn suggests absence of phytoplankton grazers; while the very low DO levels presumably reached overnight, suggest absence of high oxygen demanding fauna right from zooplankton to fish, leaving only specialised low oxygen tolerant animals to inhabit this zone. Leeches and dragonfly nymphs appear to be among such organisms. A large number of these two invertebrates were found to be closely associated with the water hyacinth in lakes Victoria and Kyoga. Clearly the effect of water hyacinth on aquatic biota is to drastically reduce the diversity of all forms of life among the mats notably plankton, floating and submerged macrophytes, macro invertebrate fauna, fish and quite possibly some amphibians and reptiles.

The impact of the above effects on the fishery resources of lakes Victoria and Kyoga deserves particular discussion. A large number of set gillnets were always encountered at the edge or among the submerged and floating macrophytic flora found to be characteristic of potential invasion sites for water hyacinth in the sheltered bays and inlets. Interviews with the fisherfolk confirmed that these bays were important fishing grounds particularly for the tilapias. The location of fishing villages with definite preference for the bays probably in search of shelter from the weather, or close by so as to exploit both the bays and the open water is further indication of this importance. Besides most artisanal fishermen cannot afford outboard engines that facilitate fishing far from land hence their concentration in the bays.

Furthermore, the biology of Nile perch and Nile tilapia, two of the three major fish species in Lake Victoria (OKARONON AND WADANYA, 1991) is closely tied to the sheltered shallow inshore waters typical of sites suitable for proliferation of water hyacinth (TWONGO, 1991b). The tilapias including the Nile tilapia breed, nursery, shelter and feed in these environments (WELCOMME, 1969) while fry and juveniles of Nile perch probably feed there. Yet, as shown above water hyacinth cover renders these environments hostile to fish and to fish food. Research is required to enhance understanding and quantify the intensity of these impacts and the magnitudes of their effects on aquatic environments and resources.

CONCLUSIONS

The escalating distribution and proliferation of water hyacinth on lakes Victoria and Kyoga will probably adversely affect the aquatic environments and resources particularly inshore. The weed will eventually impair the multipurpose social and economic benefits from the infested lakes, notably fishery resources, water transportation, hydro-electric power generation and the availability and quality of water for domestic purposes. It is, therefore, recommended:

(i) that control of the spread of water hyacinth in the watersheds of lakes Victoria and Kyoga be regarded as a high priority issue. Practical steps towards weed control should be evaluated and put in place immediately. One such step should be to form National and Regional Task Forces to spearhead water hyacinth control. The regional approach to the control of the weed is indispensable.

(ii) that timely aquatic research in environments with a potential for infestation by water hyacinth as well as on the biology, ecology and impacts of the weed in infested environment should be initiated immediately because it is through such scientific study and investigations that options on weed control and for resource management could be discerned.

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