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A review of the impacts of invasive aquatic weeds on the biodiversity of some tropical water bodies with special reference to Lake Victoria (Kenya)

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ABSTRACT

Aquatic weeds may be defined as troublesome or unsightly plants growing in abundance in aquatic situations where they are not wanted. These plants are either adapted to continuous supplies of water or are at least tolerant to waterlogged soil conditions for substantial periods of time. The wide range of adaptation to varying amounts of water, and the impossibility of sharply distinguishing between aquatic and terrestrial environments, makes it difficult to precisely define an aquatic plant. The menace of water weeds is reaching alarming proportions in many parts of the world, especially in tropical water bodies where they have led to serious ecological and economic losses. Lake Victoria, Kenya, which is the largest freshwater body in the tropics, has undergone serious ecological changes including over-exploitation of its fishery resources, degradation of the catchment area, introduction of exotic fish species and invasion by the water hyacinth, *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae), among others. The presence of the weed in the lake has led to many problems including blockage of water pumps, reduced fishing activities and increase in water borne diseases such as schistosomiasis. Positively, aquatic weeds constitute a free crop of great potential value; they are a highly productive crop that requires no tillage, fertilizer, seed, or cultivation. Moreover, these plants have the potential for exploitation as animal feed, human food, source of food to some aquatic organisms, soil additives, fuel production, wastewater treatment, source of raw materials and habitat to many organisms. This paper reviews the effects of aquatic weeds in aquatic systems with examples from some selected waterbodies and special reference to Lake Victoria.

KEY WORDS Invasive; Lake Victoria; weeds; tropical; waterbodies.

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INTRODUCTION

Aquatic weeds are higher plants that grow in water or in wet soils but some weeds may endure periods of desiccation. They usually occur along the shores of water bodies like dams, lakes and along rivers and river mouths. The distribution, permanency and quality of water available for their occupation govern their distribution and ecology. The most variable environmental factors of basic ecological importance for aquatic plants are the length of the period during which water is present; whether the water is still or moving; the availability of plant nutrients; and the quality and quantity of light penetration into the water. Factors that influence the establishment and distribution of aquatic plants include: depth, topography, types of substrate, exposure to currents and/or wind and water turbidity. The distribution of macrophytes is often related to their method of attachment (Sculthorpe, 1976).

Aquatic plants, like most water organisms, are more widely distributed throughout the world than terrestrial plants. This is because factors or conditions required by aquatic plants are uniform in general than those to which land plants must adapt to. The aesthetically pleasing appearance and unique growth form of floating aquatic weeds have been responsible for their spread to various tropical and sub-tropical countries by humans during the 1800s and 1900s. In Kenya, aquatic weeds were used to grace aquaria and ornamental ponds from where they escaped into natural or artificial water bodies causing serious problems (Njuguna, 1992).

Macrophytes are among the most productive plant communities in the world (Sculthorpe, 1976) and are known to provide nutrition for humans and herbivorous animals. In general, water plants have both positive and negative importance to man, either directly or indirectly (Mitchell, 1974).

Study area

Lake Victoria (Fig. 1) is the largest tropical lake in the world. The lake is shared by Kenya (6% by area), Uganda (43%) and Tanzania (51%). It has a mean depth of 40 m, maximum depth of 84 m, shoreline of 3450 km, a water retention time of 140 years and a catchment area of 193 000 km^2, which extends into Rwanda and Burundi. It is situated 1134 m above sea level and has a surface area of 68,800 squared kilometers. The lake is roughly in square shape; its greatest length and width being about 400 and 320 km, respectively. Much of the lake is less than 40 m deep and the deepest part, 60-90 m, is in the northeast. The bottom is mainly covered by a thick layer of organic mud, but with patches of hard substrate, sand, shingle or rock (Scholtz et al., 1990). The coastline is intended with bays and gulfs. The Kagera and Nzoia rivers are the principal influents while the only outflow occurs to the River Nile via Lake Kyoga.

The lake receives nearly 80% of its water inputs from rainfall and a similar amount is lost via evaporation (Bootsma & Hecky, 1993) (Table 1).

Parameter	Characteristic
Lake area (km^2)	68,800
Maximum Depth (m)	(92)
Mean Depth (m)	40
Volume (km^3)	2,760
Catchment (km^2)	194,000
Outflow (O)(km^3/y)	20
Inflow (I)(km^3/y)	20
Precipitation (P)(km^3/y)	100
Evaporation (km^3/y)	100
Flushing Time (V/O)(years)	140
Residence time (V/(P+I)(years)	23

Table 1: Catchment and basin parameters of Lake Victoria. Source: Bootsma & Hecky, 1993; IDEAL 1990; Welcomme, 1972; Sigel & Coulter, 1996.

Lake Victoria is an important source of affordable protein food in the form of fish. It provides employment, income, and export earnings to the riparian communities. It is a source of water, mainly taken without treatment, and is also used for transport. As well as their food value, the fish species of the lake are of important evolutionary significance and have been extensively studied.

Lake Victoria Environmental Management Programme (LVEMP) (2001) reported that the quality of Lake Victoria waters has been deteriorating over the last 30 years due to increased inflow of nutrients into the lake. Population increase within the catchment area also raises the need for more food hence, there is widespread use of fertilizers to boost food production, adding to the agricultural load in the lake. Concentrations of phosphorus have increased substantially within deep waters while nitrogen levels have increased closer to the shores.

Figure 1. Map of Lake Victoria.

As a consequence of the increase in nutrients levels, vast algal blooms have become a common feature of Lake Victoria, with blue green algae dominating, causing de-oxygenation of the water, increased sickness for populations using the lake water and high water treatment costs together with loss of deep water fish species. Fish inhabiting shallow waters are also at risk from periodic upwelling of hypoxic waters. In addition, reports also indicate increased invasion of the lake by aquatic weeds including the abnoxious water weed, *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae).

Types and characteristics of aquatic weeds

Aquatic macrophytes can be sub-divided into four groups on the basis of their water requirements, life forms and habitats. The categories include: submerged, emergent, floating leafed and free-floating macrophytes.

Submerged macrophytes are plants that are usually rooted in the substrate but are completely under the water surface. These plants cannot be established at a depth more than 10 m and are adversely affected by large fluctuation in the water level. Submerged plants have thin finely dissected leaves adapted for rapid exchange of nutrients with water. Examples include *Potamogeton pectinatus* L. (Potamogetonaceae), *Najas horrid* A. Braun ex Magnus (Hydrocharitaceae) and *Vallisneria spiralis* L. (Alismataceae). The growth rate of submerged plants has been recorded to range from 10 mg dry matter per day for *Ceratophylum demersum* L. (Ceratophyllaceae) to over 80 mg in *Hydrilla verticillata* (L.f. Royle) (Hydrocharitaceae) (Denny, 1972).

Emergent macrophytes include plants which are rooted with their principal photosynthetic surfaces above the water. They are markedly exclusive since they always occur in dense monospecific stands reminiscent of monocultures. Boyd (1969) suggested that this comes about because of their success in taking up and storing nutrients, which are later made available to young growing organs by translocation. Emergent plants such as *Typha* sp. (Typhaceae) and *Cyperus papyrus* L. (Cyperaceae) are generally rigid and are not dependant on water for support. They have both high growth rate and high biomass (Symoens et al., 1981). The emmergents such as *Typha* can only occur in shallow water or damp soils along the shoreline and are unlikely to survive large changes in lake level (Mitchell, 1974).

Floating leafed macrophytes are plants that are rooted but have floating leaves. Examples of such macrophytes are *Nymphaea lotus* L. (Nymphaeaceae) and *Trapanatans* L. (Trapaceae). These are usually restricted in the shallower areas of water bodies.

Free-floating macrophytes are aquatic plants that float on the water surface.Typical examples of free floating macrophytes include *Salvinia molesta* D. Mitch. (Salviniaceae) and *E. crassipes*. These plants are independent of depth and substratum requirements as well as largely unaffected by changes in lake levels; hence they are the greatest threat to any water body (Adeniji, 1979). A review of literature makes it clear that in the tropics, the greatest threat is posed by this group of macrophytes.

DISCUSSION

Problems of aquatic weeds

Aquatic plants are considered nuisance when excessive growth interferes with desired water uses in a number of ways (Adeniji, 1979). In line with increased industrialisation, travel and communication, agricultural productivity, increased human population and changes in consumption, problems associated with aquatic weeds have increased in the last century (Davis & Hirji, 2003).

The menace of some aquatic plants may reach alarming rates especially in the tropical regions where warm water fosters plant growth. The problem is aggravated by the increasing enrichment of water bodies by poor land use practices and other effluents from the human and industrial wastes. Less than 20 of the 700 species of macrophytes are considered weeds (Triest, 1993). Although originally perceived as a practical problem for fishing and navigation, recent research indicates that aquatic weeds are now also considered a threat to biological diversity affecting fish fauna, plant diversity and other freshwater life and food chains (Garry et al., 1997). Excessive population of macrophytes, especially floating and emergent weeds, results in exclusion of light from the lower layers of water. This can cause reduction of primary production and may also affect the various physical and chemical characteristics of water.

They can also lead to blockage of hydroelectric installations and water intakes and irrigation outlets. Submerged and free floating plants have also been reported to interfere with fishing and navigation activities. The invasion by aquatic weeds of any environment has always led to increase in diseases such as malaria and bilharzia, whose vectors use the weeds as breeding grounds as in Lake Victoria (Johnson et al., 1990; Twongo, 1996). The weeds also provide hiding grounds for dangerous organ-isms such as snakes.

It is evident that aquatic weeds are a total nuisance from the point of view of the human use of the water where they occur. It is important to evaluate the effects of the weeds on the entire ecosystem for example, on the invertebrates, benthic fauna, fish and large animals.

Effects of aquatic weeds on aquatic organisms

Mitchell (1974) stated that the appearance of macrophytes in any aquatic ecosystem leads to an increase in the density of other plants and animal species. Therefore, two major effects of these weeds on the ecosystem are habitat diversification and food source for the organisms.

a) Habitat diversification

Macrophytes physically change aquatic ecosystems in several ways which are important in habitat diversification. They slow down the movement of sediments in fast stretches of rivers (Butcher, 1933); consequently, the number of species increases in previously unproductive regions. The mesh formed by finely divided leaves of some submerged species (*Potamogeton* sp.), and the networks of filaments formed by some algae provide excellent refuge for juvenile fish (Mitchell, 1974). The structurally complex habitats formed by macrophytes coupled with periodic low oxygen levels is also known to protect several fish species from both excessive human exploitation and predation (Chapman et al., 1996; 2002). Several insect larvae and fish species such as the tilapiines use submerged macrophytes materials in the construction of nests. The older rhizomes of reed swamp emergents such as papyrus or any soft plant material present in shallow water provide a burrowing substrate for insects such as mayflies. These invertebrate fauna form a crucial link in the foodweb of natural and man-made tropical lakes (Petr, 1970).

Investigations by Bowmaker (1968, 1973) and Mitchell (1976) in Lake Kariba demonstrated that *Salvinia* mats play an important role as a habitat for young fish and their prey and, that mobile mats swept over the lake by wind assist in the distribution of fish fry. Reports from Lake Naivasha in Kenya indicated that the abundance of some invertebrates such as the water boatman *Micronecta scutellaris* (Stål, 1858), Hemiptera Corixidae, was closely related to *S. molesta* mats (Aloo, 1988). Perhaps the most important contribution of macrophytes to the ecology of Nyumbaya Mungu reservoir in Tanzania was their close association with the fish and the aufwuchs communities. In this reservoir, the major shoals of commercial tilapiine cichlids fishes such as *Sarotherodon pangani* (Lowe, 1955) and *S. jipe* (Lowe, 1955) (= genus *Oreochromis*) were reported to be closely associated with aquatic plants such as the *Cyperus articulates* L. (Mitchell,1974).

Emergent plants such as *C. papyrus* also provide special conditions needed by swamp inhabitants including the swamp worm Almaemini (Clark et al., 1987). This worm is adapted to life under anaerobic conditions and can even live for several days without oxygen. In Lake Volta, Petr (1968) demonstrated the importance of the invertebrates associated with weed beds and submerged plant surfaces while in Lake Kariba, Bowmaker (1968) noted their abundance among the floating mats of *Salvinia*. McLachan (1969) reported that the appearance of submerged macrophytes such as *Potamogeton* and emergents such as *Ludwigia* (Onagraceae) in Lake Kariba resulted in marked changes in the benthic fauna. Total mud species numbers increased from 28 to 46 in the bottom close to the base of these plants. In Lake Victoria, the introduction of *E. crassipes* led to an increase in the population of leeches, dragon fly nymphs and several mollusc species which were reported to occur under hyacinth mats (Twongo, 1996).

Furthermore, the macrophytes coverage, particularly the swampy areas are known to subject fish populations in particular to extreme physicochemical regimes that in the long-term acts as natural selection forces responsible for speciation. The fish assemblage in Lake Victoria which was previously composed of the haplochromine cichlids was thought to have evolved through this speciation mechanism. According to postulation by Greenwood (1974) and Kaufman (1992), these unique habitats together with small water bodies around Lake Victoria acted literally as boiler plates for speciation and the multiplication of cichlids.

b) Food source

Several studies using stable isotopes have reaffirmed plants, particularly aquatic plants (both C3 and C4 plants) as the main source of energy in most water bodies (Ojwang et al., 2004; 2007). Other studies using traditional gut contents analysis have shown that herbivorous tilapiine cichlids fishes such as *Tilapia rendalli* (Boulenger, 1897) and *T. zillii* (Gervais, 1948) feed on aquatic plants as their main diet. Though there are some indications of preference for submerged plants (*Elodea*, *Ceratophyllum* and *Najas*), floating plants (duckweeds, *Wolffia* spp., Araceae) and emergent plants (*Typha*) are also eaten (Sculthorpe, 1976; Blackburn et al., 1971).The development of submerged vegetation in the lower Volta was reported to have profound effects on the whole ecosystem. Fish found food and shelter in the beds of hydrophytes. Populations of *Tilapia* spp. and *Neritina* sp. (Gastropoda Neritidae), a gastropod which feeds on *Vallisneria* (Hydrocharitaceae) increased remarkably, a phenomenon which was attributed to increase in productivity in the ecosystem by both *Potamogeton* and *Vallisneria* plant species (Hall & Pople, 1968).

Other fish species such as *Disticho dusschenga* Peters, 1852, *D. mossambicus* Peters, 1852 (Distichodontidae) and *T. rendalli* also fed on *Potamogeton* and *Vallisneria*. *T. rendalli* was reported to be the only fish specialized in grazing on macrophytic plants in Nyumbaya Mungu, although the scavengers such as *Clarias mossambicus* (Peters, 1852) (Clariidae) and *Synodontis punctulata* (Günther, 1889) (Mochokidae) occasionally ingested plant fragments (Bailey et al., 1978). In the Kenyan Lake Naivasha, Oluoch (1983) reported an abundance of macrophytes in the stomach of the crayfish *Procambarus clarkii* Girard, 1852 (Crustacea Cambaridae).

It is not only fish species that depend on macrophytes as source of energy. In Lake Cabora Bassa, Bond & Roberts (1978) observed hippos, baboons, monkeys, warthog and kudus feeding on *E. crassipe*s particularly during the dry season. Waterfowls such as the Egyptian geese fed to a limited extent on stranded plants (Davies et al., 1975). Lake Naivasha supports 31,000 ducks which forage on a wide range of aquatic plants (6 spp.) and 43,000 coots *Fulica cristata* Gmelin, 1789 (Aves Rallidae) that depend largely on the submerged plant *Naja spectinata* (Parl.) Magn., Bivalvia Najadaceae (Watson & Parker, 1970; Clark et al., 1987).

The lake also supports a large population of *Myocaster coypus* (Molina, 1782), Rodentia Myocastoridae, which is reported to enjoy the emergent vegetation around the lake shore. Recent studies indicate that the decline in aquatic macrophytes in Lake Naivasha has led to the low numbers of the crayfish, *P. clarkii* (Harper, 2010).

c) Other benefits of aquatic plants

A few species of aquatic plants are directly important to man for food and for materials used in building/constructions. The Indian rice, water chestnut and delta potatoes are sources of food. Some weeds (Nile cabbage, water spinach) are used as vegetable among many African communities. In some parts of the world, the bulrush is used for building boats, floor mats and wall partitions. The papyrus, *C. papyrus*, has been utilized for weaving baskets, making mats and thatching huts especially in rural communities (Prescott, 1969).

Limnologically, aquatic plants and shoreline vegetation play important roles including beach building, the filling in of lake margins with the accompanying aging and eutrophication and prevention of shore erosion. A few aquatic plants bring about the deposition of lime, thus, after a long period of time, produce useful marl deposits. Besides these, there are many interactions between aquatic plants, water chemistry and the nature of bottom deposits (Prescott, 1969).

Macrophytes strands can act as a filter for excessive nutrients, which would otherwise lead to eutrophication of adjacent water bodies. Although the absorption may not in itself ensure the removal as the plants might re-release them on decomposition, the wet low oxygen soils favour denitrification by bacteria leading to loss of nutrients. The plants also remove heavy metals, biocides and other toxins from the water temporarily into their tissues. In theory, this could harm organisms higher up the food chain, however, the plants have various biological, chemical, biochemical and physical processes which immobilize, transform and fix the contaminants (Malthy, 1986).

Recent changes in the distribution and diversity of macrophytes in Lake Victoria

Lake Victoria has undergone drastic ecological changes since the introduction of alien fish species in the 50s and 60s. Prior to these introductions, the lake's fisheries were dominated by haplochromines which were alleged to have hindered the establishment of macrophytes in the inshore areas by constantly disturbing the substrate (Witte et al., 1992). The large populations of haplochromines were later decimated by the piscivorous Nile perch, *Lates niloticus* Linnaeus, 1758 (Latidae).

Aquatic plants along the lake's shoreline were dominated by papyrus, *C. papyrus*. Floating islands which were common during the rainy seasons consisted of populations of the emergent macrophytes which were sloughed by currents and winds. The other plants on floating islands were few mainly comprising climbers such as *Ipomoea aquatic* Forssk., Convolvulaceae. Before the invasion of the lake by water hyacinth, succession of aquatic plants were not as drastic, a phenomenon earlier reported by Russell (1942) and Penfound & Earle (1948).

Macrophytes in Lake Victoria mostly occur in the vicinity of river mouths and sheltered bays. River mouths favour the establishment of macrophytes because of sedimentation from rivers while the incoming nutrients stimulate the growth of various plant species. More than 30 families and 60 species of macrophytes have been recorded from Lake Victoria. These are dominated by Cyperaceae, of which many species have not been identified.

E. crassipes (Fig. 2) was first recorded on the Ugandan side of Lake Victoria in 1988 (Twongo, 1991). The weed reached Lake Victoria from River Kagera which originates in Burundi through Rwanda and Tanzania and enters the lake in Uganda. While the introduction of *E. crassipes* may have been accidental, the weed was originally transported from its native home in South America to be used as an-ornamental plant. By 1992 the weed was firmly established in most suitable littoral environments along the entire shoreline of Uganda (Twongo, 1996). Water hyacinth had already been reported in Tanzania (AAPS, 1990) as well as in the sheltered bays in Kenya.

The weed was confirmed to be present on the Kenyan side of Lake Victoria in 1991, although unconfirmed reports of its presence at the River Yala swamp had been received as early as 1990 (Mailu, 1999). The spread of the weed across Lake Victoria was greatly aided by strong winds which swept large masses of the weed from the bays along the north-western shores across the lake, to the northern and possibly north-eastern shores.

Currently, *E. crassipes* is widespread on the Kenyan waters of Lake Victoria occurring abundantly in Winam Gulf, Karungu Bay, Muhuru

Bay, Luanda, Usenge, Asembo Bay, Osieko Beach and along Yala Swamp. Small mats of the weed were reported to occur at Sio Port, Mbita Point and Nzoia River (Aloo, 2003). The weed is estimated to occupy a total of 5,000 hectares on the Kenyan side of Lake Victoria. The geo-climatic requirements of water hyacinth favour its growth and reproduction in the lake. Factors that lead to its increased growth and production include nutrients especially nitrogen and phosphorus. Lake Victoria is nutritionally enriched by drainage from agricultural, discharge from factories, urban waste and inadequately treated sewage effluents. The population of water hyacinth has, therefore, spread rapidly under the nutritionally favourable conditions and ambient temperatures in Lake Victoria.

Macrophytes succession in Lake Victoria after water hyacinth invasion

On the establishment of water hyacinth in Lake Victoria, the floating mat provided substrate for the establishment of other plants including terrestrial plant species. Succession of the aquatic plants has also been accelerated due to the shading effect on other plants and increase of organic matter upon the death and eventual sinking of the plant biomass. *Pistia stratiotes* L. (Araceae), *Azolla pinnata* R. Br. and *A. nilotica* Decne. ex Mett. (Azollaceae) were the most common floating macrophytes in Lake Victoria before the invasion of water hyacinth. The grass, *Vossia cuspidata* (Roxb.) Griff. (Poaceae) formed a thin layer behind *P. stratiotes* followed by *C. papyrus*, *Aeschynomene elaphroxylon* Taub. (Fabaceae), *Phragmites australis* (Cav.) Trin. ex Steud. (Poaceae) and *Typha domingensis* Pers. (Typhaceae). On establishment in mid-1990s, the large populations of water hyacinth both smothered and pushed, landwards, *P. stratiotes* and *Azolla* spp. This compact mass, the resulting debris and proximity to land led to the increase of *V. cuspidata* and *Echinochloa pyramidalis* P. Beauv. (Poaceae) communities by acting as a substrate.

Other emergents which were reported to be closely associated with water hyacinth mats were *Hibiscus diversifolius* Jacq. (Malvaceae) and *T. domigensis*.

Figure 2. Water hyacinth, *Eichhornia crassipes.*

These emergents in turn shaded and competed for nutrients resulting in the death of the latter. After the invasion of water hyacinth, floating islands consisted mainly of the hyacinth and *V. cuspidata*. Aquatic communities that were decimated by water hyacinth included the floating leafed *N. lotus* and *T. natans* and the submerged plants, *C. demersum* and *N. horrida*.

Effects of Water Hyacinth in Lake Victoria

The problems created and damage caused by *E. crassipes* are greater than those due to any other floating aquatic weed in Lake Victoria. It is no wonder that the weed has been described as truly the world‘s worst aquatic weed (Harley, 1990). The weed forms dense, impenetrable mats, which impede or prevent boat traffic in natural water courses, artificial or natural lakes, irrigation and flood mitigation canals. Detailed assessment of the impact of water hyacinth infestation on a given ecosystem and its resources might justify the huge economic tag that is required to control the vast expanses of the weed around the shores of Lake Victoria (Twongo, 1996). The rapid spread of *E. crassipes* in Lake Victoria led to serious economic, social, health and environmental impacts in the riparian states.

The weed has affected the fisheries, water supply and transport, environmental health and power generation, interfering with the lives of over 30 million people that depend on the lake (Aloo, 2003). Fish production in the lake has declined since the weed has blocked many fish landing beaches; it has infested sheltered bays which are breeding grounds of fish while in open waters the mats of the weed has swept away and entangled fleets of nets. The mats also pose obstruction to fisheries exploitation which has led to higher operation costs hence increase in fish prices. Many landing beaches have been abandoned and income-generation from the sale of fish has been negatively affected.

Water hyacinth has caused clogging of water pipes, leading to frequent water shortages in lakeshore urban centres. The infestation has occasionally resulted in disruptions, delays and rising operation costs in the transport sector yet water transport is the cheapest means of transport for the lakeside communities. The weed has grossly interfered with cross border trade between the three East African states. Decomposition of the weed requires large amounts of oxygen which leads to a drop in levels of oxygen in areas infested by the weed, reducing survival of aquatic organisms especially fish. The decomposed material also leads to pollution of the water making it unfit for any use. The weed has also been reported to impact negatively on the health of lakeside communities, since it provides optimal habitat for mosquitoes and snails which are vectors for malaria and bilharzia respectively (Twongo, 1996).

While some studies have been carried out in Kenya to investigate the association of water hyacinth with various vector borne diseases, large number of snails are usually found among water hyacinth mats in Lake Victoria. Dazo et al. (1966) reported a positive association between bilharzia vectors *Bulinus truncatus* Audouin, 1837 (Gastropoda Planorbidae) and *Biomphalaria alexandrina* Ehrenberg, 1831 (Gastropoda Planorbidae) and various aquatic macrophytes including water hyacinth in Egypt. There is an urgent need to monitor the impact of water hyacinth infestation on incidence of water associated vector-borne diseases. The weed also provides a hiding place for dangerous organisms such as snakes. Water hyacinth is now a widespread weed occurring in dams, rivers and home aquaria all over Kenya. The weed has formed a green carpet on the Nairobi dam, situated in Motoine River Valley South of Kibera slums in Nairobi, covering the entire water surface. Today, the dam has completely dried out thus affecting the recreational activities that existed in the dam before invasion by water hyacinth (Aloo, pers. obs.). Currently, the weed has been reported to be a threat to the Athi River, which is Kenya's second largest river. In Masinga dam, a few patches of the weed have been observed floating on the water.

Positive attributes of water hyacinth in Lake Victoria

Aquatic weeds have some positive effects in the water bodies where they occur. In Lake Victoria, reports have indicated that there has been a resurgence of the endemic fish species especially some Cichlidae of the genus *Haplochromis*, *Clarias gariepinus* (Burchell, 1822) (Clariidae), *Protopterus aethiopicus* Heckel, 1851 (Protopteridae) and Elephant-snout fish *Mormyrus kannume* Forsskål, 1775 (Mormyridae) as a result of the invasion of the lake by the weed (Bugenyi & Van de Knaap, 1998; Njiru et al., 2000; Ogari, 2000).This is because mats of the weed provide hiding habitat for many fish species (Ogari, 2000). The swampy areas, particularly the remaining wetlands along the shores of Lake Victoria, are recognized as refugia to some of the native fish populations (Denny, 2000). Most of the fish species inhabiting the swampy areas are tolerant of extreme environmental conditions (Chapman et al., 2002). For example, *P. aethiopicus* and *C. gariepinus* are physiologically hardy and have structures that enable them access to free atmospheric oxygen.

The structural complexities of the swampy habitats coupled with periodic low oxygen levels protect a number of indigenous fish species from both excessive human exploitation and predation from Nile perch. Species richness has been observed to be specifically higher in the swampy areas along the shores of the lake than in the interior areas (Chapman et al., 1996; 2002; Balirwa et al., 2003). These are areas that physiologically limit the foraging abilities of Nile perch, which frequent waters of higher oxygen content. On the other hand, the unique ability of macrophytes to improve water clarity favours both mate recognition amongst the haplochromine cichlids and at the same time promoting the coexistence of the species with the Nile perch, since the predatory techniques of Nile perch are best suited to waters of intermediate turbidity.

E. crassipes has been inhabited by many aquatic insects which are an important diet to the juveniles of many fish species. In some parts of the lake, there has been increase in the abundance of aquatic birds which depend on water hyacinth as their food and resting stations in the course of their foraging activities. Water hyacinth has also been utilized for various purposes such as fodder, raw materials and for water purification purposes (Twongo, 1996). The weed's role as water purifier is of great importance in Lake Victoria where many lake side municipalities' wastewater treatment plants are presently broken or are ill maintained, thus the amount of raw sewage flowing directly into Lake Victoria is enormous. This enhances the proliferation of the water hyacinth and other aquatic weeds.

Re-appearance of water hyacinth in Lake Victoria

Currently, water hyacinth has abundantly reappeared in the lake (pers. obs.). Biological control method through the introduction of the natural enemies of the plant, *Neochetina eichhorniae* Warner, 1970 and *N. bruchi* Hustace, 1926 (Coleoptera Curculionidae) was widely used in the early years of invasion. This method was believed to have reduced the total area covered by hyacinth from 6000 ha in April 1998 to 400 ha in 2001 (Wawire & Ochiel, 2001).

Today, there have been serious resurgences of the weed especially around Homa Bay and Kisumu areas. Unpublished reports also indicate that there is an ecological association between water hyacinth and the hippo grass which is also found abundantly in the lake. Thus the case of succession of the weeds in Lake Victoria is a subject of interest to ecologists and require further studies.

CONCLUSIONS

The impacts of aquatic weeds are diverse and their significance in ecosystems, especially in large water bodies cannot be ignored. The weeds need to be managed prudently to allow sustainable exploitation and exploration of mitigation measures, to minimize potential negative impacts often associated with their massive proliferation. The spread of aquatic weeds in the tropics is a matter of great concern and concerted mitigation efforts are required to allow for continued use of enormous aquatic resource potentials in the tropics. This is critical as the majority of livelihoods in the tropics depend on the water bodies and their resources. In Lake Victoria, plants succession due to introduction of invasive species, *E. crassipes* has led to several ecological changes in the lake with far-reaching socio-economic consequences (Aloo, 2003).

Although aquatic weeds have caused serious problems in many waterbodies, their positive effects cannot be ignored especially on the biodiversity of such systems. The weeds not only provide shelter to many aquatic organisms but they are also a source of food to some fish species and other vertebrates and provide raw materials for use in several livelihood activities (Dean, 1969; Bond & Roberts, 1978; Mitchell, 1974; Oluoch, 1983). In Lake Victoria, for example, the appearance of *Eichhornia* has led to an increase in the catches of *C. gariepinus*, *Haplochromis* spp., *P. aethiopicus*, *M. kannume* and many haplochromine species (Njiru et al., 2000). Many of these fish species were a favourite dish to local communities in the pre-Nile perch Lake Victoria. Given the magnitude of aquatic weeds infestation in Lake Victoria, this paper recommends the following:

- a survey of the extent and nature of the aquatic weeds infestation should be undertaken to establish the magnitude of the problem in Kenya's aquatic systems including small water bodies;
- multidisciplinary research should be carried out on aquatic weeds to understand their effects on the aquatic systems and their potential benefits to both humans and other organisms;
- there is need to investigate the relationship between water hyacinth and the hippo grass in Lake Victoria;
- control strategies should take into account the potential effects of the method on the flora and fauna found in the water body.

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