

Household Welfare Impacts of the Water Hyacinth
(*Eichhornia crassipes*) in the Kenyan Side of Lake Victoria

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ABSTRACT

Lake Victoria is an important source of livelihood for not only Kenyans residing next to it but the rest of East Africa and The Great Nile Valley. Nevertheless, Lake Victoria and therefore the livelihood of fishermen residing next to it has been adversely affected by the water hyacinth (*Eichhornia crassipes*) as reported in many fora. It becomes imperative therefore that the effects of the hyacinth if any are investigated and monitored in order to forestall and adverse impacts. The first step in such a process will needless to say require an inquiry of whether impacts on household welfare negative or otherwise exist. A study was therefore undertaken aimed at answering the questions: Is the water hyacinth deleterious to household welfare? Is this impact greater for poorer sections of society? After clarifying what is meant by household welfare, an analytical framework is presented and applied to household cross sectional data from five sub-locations adjacent to the Kenyan waters of Lake Victoria. A randomly selected sample of 350 households was interviewed using a questionnaire similar in design to the World Bank's LSMS format. The instrument has the advantage of enabling a comprehensive assessment of many aspects of welfare rather than giving precise numerical values since many day-to-day policy decisions are made with the former, giving a general background of the field on which the policy play. A set of households resident in areas clear of the hyacinth was set out as a control group in this study.

Majority of households reported that the hyacinth had deleterious welfare effects and OLS results strongly confirmed this result. Household expenditure (a proxy for income) was consistently larger in non infested areas in the estimated Engel relationship, 'income' coefficients were negative as expected, indicating an inverse relationship between the share of food in household budget and income. Household capital coefficients —human, physical and social all had the expected signs In addition to these main results, constructed hypothetical markets for hyacinth control indicated non-zero values of willingness to pay which intuitively means that such households were better off without the hyacinth.

These results have fundamental lessons for research and policy. It is evident that the poor have a lot at stake when faced with such a crisis and therefore, the hyacinth control effort should be concentrated in those areas where the poor live. The importance of education which is a manipulable factor both in the short and longterm and can improve the flexibility of households to the changing economic circumstances that accompany hyacinth invasion is noted. Measures that improve incomes would go a long way in mitigating or lessening the adverse welfare impacts of the water hyacinth.

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GLOSSARY

Household: This refers to one or more persons who usually sleep in the same dwelling and take meals together during at least three of the last twelve months preceding the interview. Obvious exceptions to this rule are (i) that person identified as the household head even if they spent less than three of the twelve months in the household (ii) persons joining the household and expect to be long term residents such as new born infants or new spouses (iii) children living away say in boarding schools. Servants who have a contract, written or unwritten, with the household and are paid in cash or in kind according to that contract are not counted as household members. In contrast, servants who do not have a written or verbal contract who may receive compensation for services rendered that is arbitrarily determined and is more like a gift than a payment are considered as household members for the purposes of this study. A household need not be made up of blood relatives hence, any other unrelated person(s) who has resided in the dwelling for at least three of the last twelve months is considered a household member.

Household head This is the person who is recognised by the rest of the household members as the major decision maker and therefore head. It is understood that such are the persons who make most of the important decisions relating to the household.

Household size This is simply the number of observed persons who make up the household in question.

Food share: This is the amount of household expenditure devoted to food expressed as a fraction of total household expenditure.

Household welfare: In this study, the food share denotes household welfare, which is a rough representation of a household's standard of living or loosely speaking, welfare. A large food share is an indication that the household in question is close to or below a 'poverty line' since such a household most-often-than-not has little income devoted to other commitments such as health, shelter and education.

Adult equivalents: This is a number that scales the observed household size by a weighting system, which is done so as to enable the comparison of households of varying sex/age compositions. In this study however, only the age of different household members is assumed to determine their respective equivalencies. The study adopts equivalence scales developed for Kenya *viz*, a scale of 0.24 adult equivalents for household members aged less than four (4) years, 0.65 for all household members aged between four and fifteen years and a scale of 1 for all other household members.

Dependency: This is taken to be the ratio of income earners to household size. It represents a measure of vulnerability to economic shocks since households depending on fewer economically active members are more vulnerable should those members cease to bring in income into the household for one reason or another.

Income diversity: This as opposed to dependency is the number of different income sources from which the household normally draws its income. It is a measure of how vulnerable to economic shocks a household is

since the more diverse household income sources are, the less the likelihood that all sources are affected equally by shocks at any given time.

Capital: This refers to 'stuff' that augments production but is not completely consumed upon each use. Ultimately, any stock of capital is a cumulation of past flows of depreciation, with past flows netted out. In this study, three elements of capital are envisioned. (i) physical capital (ii) human capital (iii) social capital.

Physical capital: This refers to the stock of natural and manmade resources that can be used to produce a future flow of income. Its origin is in the spending of time and other resources constructing tools, plants, facilities and other material resources that can in turn be used in augmenting the production of other products. Physical capital has been operationalised as the total present value of physical assets owned by the household.

Human capital: This represents the acquired knowledge and skills that any single individual can bring into productive activity. It is formed consciously through education and training and unconsciously through experience. Human capital is created by changes in persons that bring about skills and capabilities that can make them able to act in new ways. In this thesis, human capital is operationalised and measured by the level of education of the household head as well as the number of years at his/her present occupation or in other words, experience.

Social capital: Social capital although a difficult concept to define let alone measure, is definitely an important feature of human association which determines the success rate of many forms of human undertakings. It has been defined as a collection of networks, including tacit knowledge, an aggregation of reputations and organizational capital which can be interpreted in the context of organisational theory as a social means of coping with moral hazard and incentive problems. It is also defined as the shared relationships, norms, knowledge and understanding that has been used by resource users to sustain the productivity of natural capital over the ages. It is created when individuals learn to trust one another so that they are able to make credible commitments and rely on generalized forms of reciprocity rather than on narrow sequences of *quid pro quo* relationships (Ostrom, 1992). One central theme that runs through various definitions of the concept is trust. Social capital in this study is operationalised and measured as the density of the network of contacts or connections between individuals. The magnitude of the household's associational activity and thus, the number of remittances (both cash and in kind) into and from the household is taken to be a measure of social capital albeit crude but sufficient given the circumstances to suffice as an approximation of the amount of social capital that any household has a claim to.

Expenditure: This is operationalised as the monetary value of all reported consumption goods and services acquired by the household within one calendar year. However, certain frequent expenditures which are subject to reporting errors due to their nature are given a shorter reporting period of one week in order to avoid misreporting expenditures on them.

Poverty: The poverty lines developed from the latest nationwide welfare monitoring survey are used to distinguish households. An overall poverty line of Ksh 1,452 and a food poverty line of Ksh 1,086 per adult per month

developed by inflating the 1997 poverty lines by the inflation rates 6.6, 3.5 and 6.2 for the years 1998-2000 are used in this study to

ACRONYMS

CILSS	Cote d'Ivoire Living Standards Survey
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FAO	Food and Agriculture Organisation of the United Nations
ICRAF	International Centre for Research in Agroforestry (now World Agroforestry Union)
IFPRI	International Food Policy Research Institute
ILO	International Labour Organisation
IUCN	World Conservation Union (formerly International Union for the Conservation of Nature)
KARI	Kenya Agricultural Research Institute
KICK	Kisumu Innovation Centre, Kenya
LBDA	Lake Basin Development Authority
LSMS	Living Standards Measurement Survey
LVEMP	Lake Victoria Environmental Management Programme
MCBI	Marine Conservation Biology Institute
NASA	National Aeronautics Space Agency
NSTL	National Space Technology Laboratories
OLS	Ordinary Least Squares
PNG	Papua New Guinea
SPSS	Statistical Package for Social Scientists
UNEP	United Nations Environmental Programme
UNICEF	United Nations Children's Fund
USGS	United States Geological Society
WHO	World Health Organisation
WMS	Welfare Monitoring Survey (I, II & III)
WRI	World Resources Institute

DEDICATION

To my parents Wavinya and Maweu whose love, dedication and encouragement are unsurpassed

CHAPTER ONE

1.0 Introduction

Large lakes play an important role in the economy and overall prosperity of mankind, being used for many purposes—including domestic and industrial water supply, irrigation, transportation, water borne commerce, mineral extraction, waterfowl habitat, fishing, aquaculture, recreation and waste assimilation. Many of the worlds large lakes form international boundaries and moreover, most of them have special aesthetic appeal and spectacular beauty (Herdendorf, 1990). Most of the above attributes are true for East Africa's Lake Victoria.

1.1 Lake Victoria

Lake Victoria (see figure 1) ranks third world-wide in area expanse after The Caspian Sea and Lake Superior and eighth in volume although is not among the 50 deepest lakes (Herdendorf, 1990). It is the second largest freshwater lake in the world, after North America's Lake superior, assuming that the waters of the Superior can still be regarded as fresh (Okidi 1994). Lying in the western arm of the Great Rift Valley, it straddles the three East African countries, Kenya, Uganda, and Tanzania, which control 6, 45 and 49 percent of the lake respectively. It is the largest tropical lake in size, species number, biomass and ecological diversity (Herdendorf, 1990; Barel *et.al.* 1991). The lake is located between latitude 0°20' North to 3°South and longitude 31°East to 34°52' East and occupies an area of 69,482sq km containing a volume of 2,700 km³. It lies at about 900 metres and is surrounded by relatively low lying land averaging 1134 metres above the sea level around its shores (Ongweny, 1979; Lewis *et.al.* 1988).

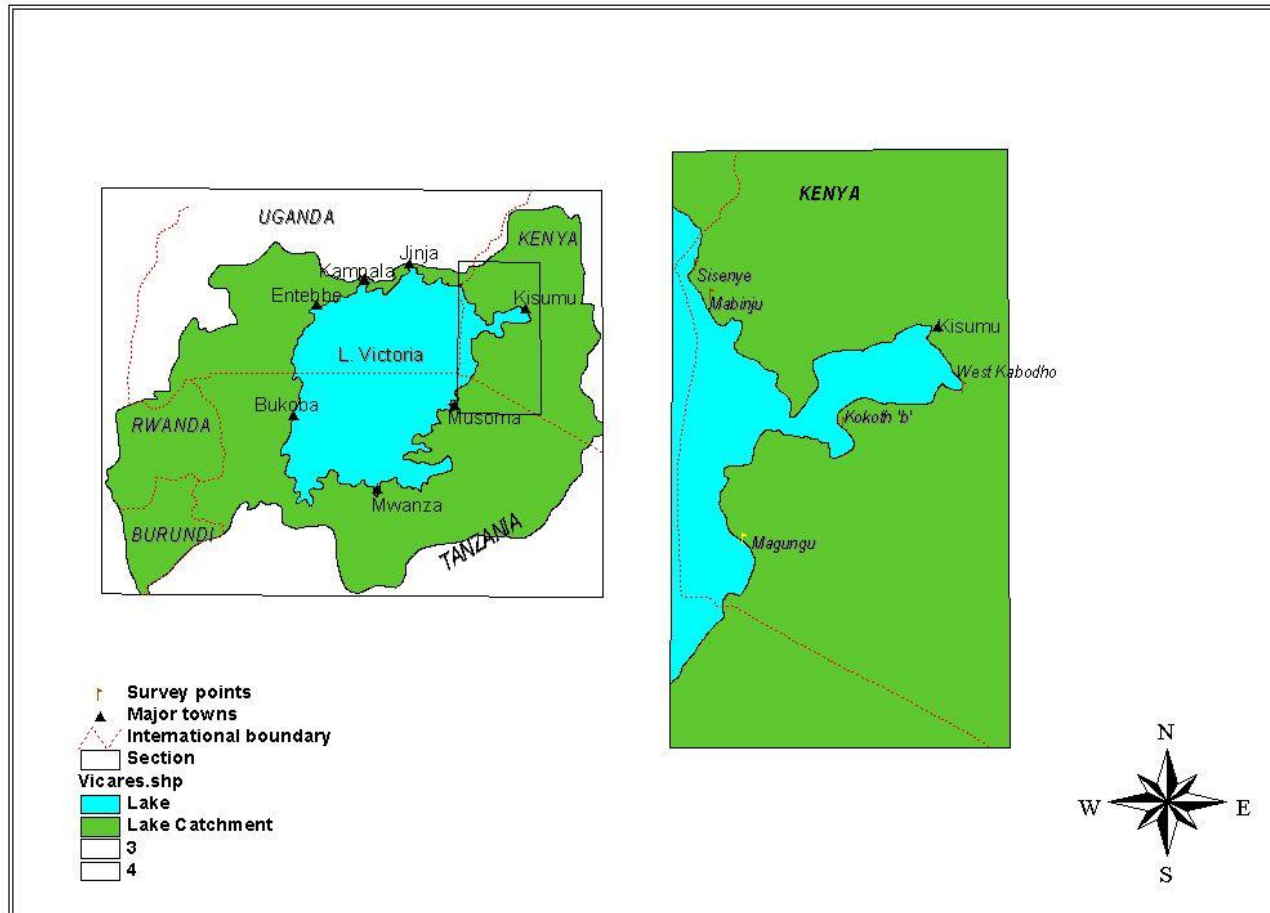


Figure 1: 1 Sketch of Lake Victoria and relative position of study sites.

Its drainage basin covers an approximate area of 266,000 km², 16 percent of which lies within Kenyan borders and is one of the five drainage basins within the country. The basin has a mean runoff of 149mm, an evaporation of 1096mm and a rainfall of 1245mm per annum (Heyer *et.al* 1976; Corbett *et.al.* 1999). Mean annual temperature ranges between 20-24°C. The lake has a mean depth of 40 metres (Ongweny 1979, Okidi *et.al* 1982) and a maximum of 92 metres and is of tectonic origin (Herdendorf, 1990). The lake is about 337 km long at its greatest length, and stretches about 240 km at its greatest width and has a convoluted shoreline of around 4,828 km (Hickling, 1961) with about 600 km making up the Kenyan shoreline. The open water is bounded especially along the southern, north-western and northern shores by large and shallow swampy bays occupying a large portion of the total area and are ecologically different from the open water.

The area is rainfall deficient and the Kenyan side, enjoys a poor to good rainfall reliability with some areas having a 15-30% chance of rainfall falling below 762 mm per year (Republic of Kenya, 1991). The lake has the Nile River as its main outlet, and the largest single affluent is River Kagera flowing into the lake at the southern reaches from the Rwandan highlands accounting for about 40 percent of the total annual inflow¹. Most of the remaining surface inflow comes from rivers from the Kenyan highlands, which account for a further 35-44 percent of the total annual inflow². Most of them pass through natural woodlands as well as agricultural and industrial zones, the latter two rendering them more susceptible to pollution (Madati *et.al.* 1982; Okidi 1994; Afullo, 1995). The main rivers from Kenya include, the Kuja, Awach (or Kibuon), Miriu, Nyando, Yala, Nzoia and Sio. Evaporation (ranging from 2,000-2,200mm p.a.) accounts for 95 percent of water loss from Lake Victoria while the remainder is accounted for by outflow through the Nile.

Most of the Winam gulf lying in the Kenyan portion of the lake is less than 20 metres deep and thus, is significantly stirred down to the bottom. The water at the bottom is well oxygenated, the nutrients well distributed, photosynthetic production high therefore providing a site rich in food from which fish can feed, typical of eutrophic lakes (Afullo 1995). However, the construction of such 'barriers' such as the Owen Falls dam in Jinja can enhance the ability of pollutants to stay longer in the lake's waters (*ibid*).

There is no definite season and a small portion at the southern shores of the Kenyan side is relatively drier with around 800 mm of rainfall per year while the remaining area enjoys around 1,200 mm per year. A great part of the area around the Kenyan side of the lake is largely dry subhumid to semi arid non-semi desert with moisture indices varying just more than 0.6 E° to just slightly more than 0.2E° (Republic of Kenya, 1991). The land has a low forest potential which supports a variable parklike woodland vegetation cover consisting of moist taller woodlands with high grass in the wetter northern

¹ Surface water contributed by rivers comes almost entirely from rivers emptying into the lake at Kenyan and Tanzanian shores.

² Annually, approximately 7,000 cubic metres of water empty into the lake from Kenya.

reaches through dry shorter woodlands with low grass in the drier parts. There are some 40 species of *Commiphora* in Kenya, which is a plant of great ecological interest, also found in a limited area immediately adjacent to the Northern and Central shores of the Kenyan side of the lake. The area is also home to Topi, Warthog, Coke's Hartebeest, Roan Antelope, Waterbuck, Impala, Buffalo found distributed unevenly and in unknown densities especially in the non humanised area (*ibid*). The agroecological zones that circle the lake run from LM3 to LM5, areas that are particularly semi arid (Jaetzold and Schmidt, 1982). The soils are moderately deep to deep, clayey in texture, and usually well drained and considered to be of moderate fertility, but this is declining because of continuous cropping (Republic of Kenya, 1991; Geheb, 1997).

1.2 Lake Victoria--Economic importance

The lake has since unrecorded time supplied to the lakeshore inhabitants protein rich fish, fresh clean water for the homesteads, water for livestock and also as a route way for trade and transport within each country and even between the countries. Lake Victoria lies in one of the most highly populated areas in the world, serving as a source of livelihood for over 25 million people in Uganda, Kenya and Tanzania³ (Ochumba 1994, Hirji *et. al*, 1998; Mailu 1999). The gross economic product from the lake region is in the order of US\$3-4 billion annually, and is principally based on subsistence and cash crop agriculture supporting the population at incomes that range from US\$90-270 per capita (Hirji *et .al.*, 1998; Mailu, 1999). It is also a source of fresh water for the local communities, irrigation, and electricity generation. Other benefits include tourism, transport, revenue generation, employment, purification and dispersal of waste (Muli 1996). For a long time, the communities living in the basin formed by this great water body have depended on it for their very livelihood- fishing for food and barter or sale to obtain the much-needed alternative food items. It also serves as a route way for trade and transport within each country or between the countries. It also provides fresh clean water for the homesteads and waters the cattle that roam the shores belonging to the Luo who were initially a pastoralist society (Ocholla-Ayayo, 1976) and is also a home for wild animals and birds (Ayot, 1977; Ochieng, 1979). To countries such as Uganda, Sudan and Egypt, it is the source of the water used to generate hydropower as well as a source of water for irrigation. This is a lake of great importance not only to the riparian countries but to the entire Nile basin which has an estimated 84 billion cubic meters of water (Okidi, 1988). The Egyptian authorities for instance took bold steps to ensure an uninterrupted flow of water from the lake through the Nile and this can help shed some light on the gravity of issues regarding this lake (Wallis, 1997)⁴. Luckily, the 73 year old treaty may soon be under a new legal framework to be signed by 10 riparian countries (DN, 7 September 2002).

³ The lake catchment provides for the livelihood of about one third of the combined population of the three riparian East African countries and about the same proportion of their combined GDP.

⁴ Particularly since the 1929 Nile water agreements and a series of diplomatic exchanges between 1949 and 1952 concerning the Owens falls dam in Uganda in which all parties agreed to avoid any actions that may adversely affect the flow of the Nile from Lake Victoria.

Fishing both commercial and artisanal is one of the most significant economic activities especially in Kenya. The lake acts as a source food, especially protein rich fish, energy, drinking and irrigation water, transport and as a repository for human, agricultural and industrial waste. An estimate for the entire lake shows annual catches of between 400,000-500,000 metric tonnes worth some US\$300-400 million and employing an estimated 100,000 people although over 2 million are indirectly engaged through forward and backward linkages in related activities (Anon, 1996a; Hirji *et. al*, 1998). It accounts for over 90 percent of all fish landed from freshwater lakes in Kenya⁵ (Ogutu, 1988; Republic of Kenya, 1998). Between 1968 and 1987, there was an estimated increase of fish tonnage by about 4,800 tons annually and an increase of 28 percent between the 1986/91 and 1991/97 (Mailu, 1999) periods, an apparently increasing trend even after water hyacinth invasion. Fishing effort has climbed steadily since independence and between 1979 and 1993, the Kenyan sector expanded by about 90,300 fishermen (Geheb *et. al*, 1997).

The fishery has undergone profound changes over time and the evolution from an originally subsistence or part time mode of exploitation to a more specialised mode is explained by three main factors. These are the scarcity of agricultural land and of alternative employment opportunities around the lake and the specialisation of some riparian ethnic groups in fishing activities (Gréboval, 1989). Indeed, the Luo who occupy the Nyanza gulf area are arguably more specialised in fishing than other East African ethnic groups living along the entire lakeshore. Fishing intensity in Kenya has remained high leading to more intensive exploitation and the shortage of agricultural land is particularly more intense around the Nyanza gulf than elsewhere around the lake. In such a context, fishermen can remain actively involved in fishing activities even as it becomes less and less productive and profitable as capital and labour appear limited and/or highly immobile (Panayoutou 1982, Geheb *et. al*, 1997).

1.3 Lake Victoria—an unfolding crisis

Degradation of aquatic ecosystems due to unplanned or poorly regulated anthropogenic activities undermines the economic utilisation of many freshwater systems. The Lake Victoria ecosystem has undergone profound disruption since the 1920s due to several interrelated forces. Cumulative impacts of the intentional and/or accidental introduction of exotic species (Nile Perch and Nile Tilapia) and water hyacinth, eutrophication and/or pollution from point and non point sources—untreated domestic and industrial sewage and agricultural effluents—soil erosion, transport and recreational activities, lake level changes, siltation due to deforestation of the watershed⁶, proliferation of water hyacinth and degradation of wetlands have wreaked havoc on this once species rich ecosystem (Crul *et.al*. 1993; Muli, 1996; Hirji *et.al*. 1998; Roach, 1999). The consequences include an unstable fishery, loss of biodiversity and accelerated eutrophication, signs which

⁵ Statistics show that more fish are landed at the Kenyan sector though smaller than that of its neighbors.

⁶ In 1999, scientists from the Kenyan based ICRAF identified a plume of colour in the water by examining satellite imagery and what was concluded was that, this soil came from areas that had been deforested.

include an increase in chlorophyll concentration, and rates of primary productivity, more frequent blue-green algal blooms and a decrease in water transparency (Hecky, 1993; Hirji *et.al.* 1998; *The East African*, 2001). Algal growth since 1960 has increased five fold, reducing the transparency of lake water while it has been estimated that nutrient inflow since the 1950s has increased three fold (Hirji *et.al.* 1998). A large proportion of Nitrogen and Phosphorous entering the lake comes from runoff from agricultural activity (Anon 1996). Lake Victoria is reported to have sufficient nutrients available to aid the rapid growth of the water hyacinth (Mailu, 1998).

Decomposition of organic matter from untreated domestic sewage, discharges from agro processing industries and from the decomposition of algae and water hyacinth may have disastrous effects on the amount of dissolved oxygen in large segments of the lake bottom. Domestic sewage has five major characteristics: a high bacterial content, dissolved organic and suspended constituents, settling solids (organic and inorganic), high nutrient concentration⁷, and floating—organic or inorganic material. These constitute a serious amenity problem, which interferes with primary production and affects self purification (Bugenyi, 1992). Falling in an area with a rainfall deficiency coupled with a water balance giving a high residence time to substances discharged into the lake (Anon, 1996) as well as a partially barred outflow, the implication is that, most of the pollutants entering the lake (see table 1.1) remain in it (Bugenyi, 1982). Pollution from industrial effluent and uncontrolled discharge from mercury based gold extraction enterprises are also threatening the supply of drinking water from the lake, posing a serious threat to public health and the fishery. Industrial plants that rig the lake have been pouring sewage and waste into L. Victoria. For instance, two million litres of such pollutants are estimated to flow in daily from Tanzania alone (ENN, 1997). These conditions have a potential of causing massive fish kills (Hirji *et. al.*, 1998).

Amidst all this, a decline in catch per unit effort (CPUE), mean size of perch caught, and drop in fertility have been recorded lately and are signs of overfishing, a scenario which the international market is partly responsible for (Wilson *et. al.*, 1999). This is apparently at a time when fishing effort has expanded (Geheb *et. al.*, 1997). As a result of uneven exploitation of the fishery resource, an economic and social; distance has been growing between migratory fishers and a sedentary population of both fishers and non-fishers, between large-scale and smallscale fishing operations and between owning and non-owning classes (Wilson, *et. al.*, 1999).

⁷ Mainly rich in Nitrogen and Phosphorous.

Table 1: 1 Estimate of pollution discharges and outflow of nutrients for L. Victoria, (tons per year)

Type	Nitrogen	Phosphorus
River inflow	38,000	9,500
Rainfall	4,560	--
Sewage	400	146
Discharge to Nile	2,500	500
Water storage	26,180	6,246
Retention in sediment	14,280	2,900

Source: Anon, 1996a, p263

Prior to the introduction of the Nile Perch and the Nile Tilapia (*Lates niloticus* in 1950s and *Oreochromis niloticus* in 1960s respectively) there were between 350-400 species of the family cichlidae over 90 percent of which were endemic to the lake. In 1978, cichlids contributed about 80 percent of the biomass and Nile Perch about 2 percent, the remainder comprising of the introduced Nile Tilapia and native non-cichlids. By 1983, Nile Perch comprised 80 percent of the catch with the rest composed of Nile Tilapia, a single indigenous species, the 'omena' and few other native species (Hirji *et.al.* 1998). By the end of the 1990s, problems were noted as the fishery was getting into a new phase characterised by low productivity. For instance, the biomass index for all species is reported to have fallen from 2.1 to 1.5 million tonnes between August 1999 and February 2000 (*The East African*, 2001). However, to avoid the *post hoc ergo propter hoc* fallacy⁸, a parallel study is currently being undertaken so as to establish the relationship between hyacinth invasion and fishing.

Aquatic weed problems in freshwaters in Africa are caused by two groups of aquatic macrophytes; those native to Africa and those alien to Africa. The latter are more problematic since in the absence of environmental controlling factors present in their native range, they are able to exploit aquatic habitats and build up large populations outside their native homes (Mitchell *et al*, 1990). First sighted on Uganda's Lake Kyoga in 1987 and L. Victoria in 1990, the water hyacinth (*Eichhornia crassipes*), a new entrant into the Lake Victoria ecosystem (see plate 1.1) is one such plant. It obstructs navigation and can act as a breeding ground for a number of disease vectors such as those transmitting malaria and schistosomiasis (Bakar *et.al*, 1984, Gangstard *et.al*, 1990; Bos, 1997). It also reduces levels of dissolved oxygen, the penetration of sunlight for lake phytoplanktons, restricts fish breeding and nursing areas, limits access by fishermen to landing areas, impairs water supply and encumbers lake transport as well as hydroelectricity generation (Gopal, 1987; Njoka *et.al.*1988; Otieno and Wangila 1993, Bos, 1997; Bugaari, *et.al*, 1998; Mailu, 1999; FAO, 2000).

⁸ The error of deducing cause from a sequence—after this, therefore because of this.



Plate 1. 1 Water hyacinth infestation, Sio Port, Busia District, (2001)

Notice the relative ease with which a boat can be rowed along the water at the point shown with the blue arrow where we have water lilies as opposed to the energy required to navigate the boat through the relatively thick mass of water hyacinth (middleground)

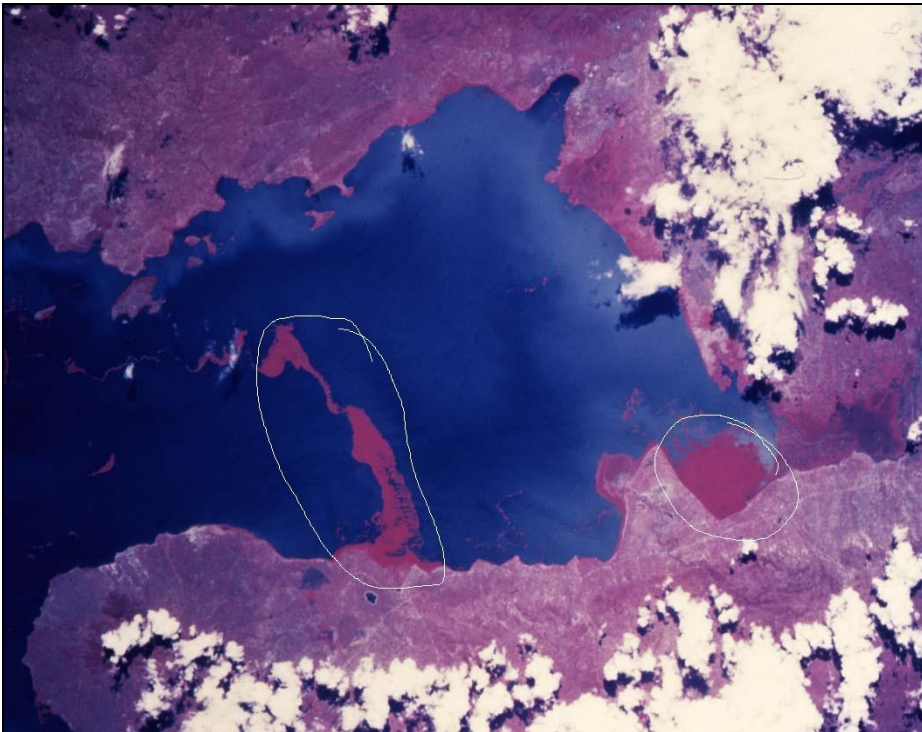


Plate 1. 2 Satellite image showing L. Victoria's Winam Gulf. (1997)

Note the Hyacinth infestation (circled) and compare with the infestation on the next image.

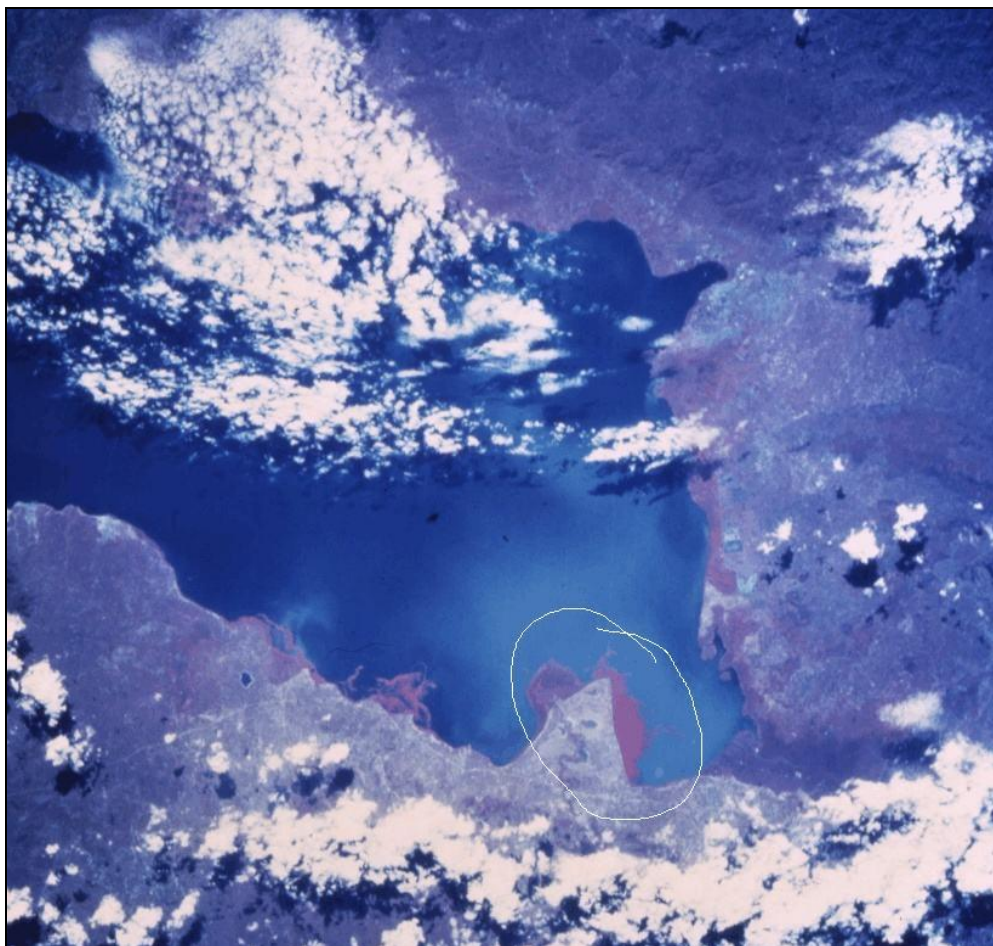


Plate 1. 3 Satellite image showing L. Victoria's Winam Gulf (1998)

Notice that on this later satellite image, the (circled) hyacinth infestation had receded. Could it be attributed to its movement to other areas or was it infested by weevils and eventually sunk?

1.4 Control of the water hyacinth in Lake Victoria

There was a growing consensus between the three East African states that the water hyacinth had become a threat and therefore had to be controlled. In 1994, a tripartite agreement between the governments of Kenya, Uganda and Tanzania was signed and this set in motion a collaborative process of project preparation which encompassed among other activities water hyacinth control and on March 3, 1997, the LVEMP was declared effective. The ultimate aim of pest control is to reduce the pest population to a level at which, no further reductions in pest populations are profitable i.e. below which the extra costs of control exceed the extra revenue (or more generally, benefits) gained by additional control (Begon *et.al.*, 1990). This is sometimes known as the economic injury level for the pest—or if social and amenity values are incorporated, the aesthetic injury level. However, despite great advances in pest control, water hyacinth has survived all attempts at total extermination in the areas where it has spread and hence, the use of the word control as opposed to removal.

1.4.1 Biological control

Biological control is the use of biological organisms to keep in check the spread of other organisms. There are attempts to control water hyacinths' proliferation by these means. Such efforts include the use of biological agents notably host specific weevils; *Neochetina bruchi* and *Neochetina eichhorniae* that have proved successful in other hyacinth infested areas such as India, South Africa, Argentina, U.S.A., Australia and Sudan. Research into biocontrol of *E. crassipes* began in 1961 and control agents released 10 years later. In 1974 for instance, *N. eichhorniae* was released in the state of Louisiana for the biological control of water hyacinth and by 1976 it was well distributed throughout the state. The area covered by water hyacinth however remained high until the insect population increased in 1979. A sharp drop in area covered by hyacinth then followed but from 1980 to 1983, the hyacinth population recovered, ostensibly due to a reduction in the host specific *N. eichhorniae* population (Cofrancesco *et.al.* 1985). This was attributed to the natural dynamics of pest-host relationships. In USA, The moths *Sameodes albiguttalis*, *Agiconia infusella* and *Arzema densa* and the mite, *Orthogaluma terebrantis* have been found to control water hyacinth although these have not been tried out in Lake Victoria. Further research shows that *Neochetina* weevils are sensible options for hyacinth control (Center *et. al.* 1999). Several insects are therefore available but the most reliable agent for control is probably *N. eichhorniae* (Pieterse, 1990). Recently, a species of the fly *Thrypticus* that feeds inside the weed's petioles was found in Iquitos, Peru and tests on its efficacy are in progress (ENN, 2000).

Biological control is a cost-effective method of pest control with nearly 31 percent success out of all cases where agents against weeds have become established (Waage and Greathead, 1988). Thus, biological control is not always guaranteed to succeed as detailed ecological and taxonomic understanding, trained manpower and perseverance are required. Even where biological control alone is insufficient as a total control strategy, it has an integral place in a larger control scheme (Begon, *et. al* 1990).

Studies carried out on Kariba weed (*salvinia molesta*) for instance indicate that the use of biological control agents as opposed to chemical applications had a benefit-cost advantage of around 500:1 (Chikwenhere and Keswani, 1995). Over a five year period, 450,000 weevils were released in the Sepik river in Papua New Guinea and hyacinth infestations were reduced from 27 square kilometres to just seven (CSIRO, 1998). Similarly, over the 1996-1999 period, over 100,000 adult weevils were reared and released over the Kenyan shores of the lake extending from Busia to Migori districts (Ochiel *et.al.* 2001). The aim of the implementers of biological control, KARI was to achieve an overall weevil density of five weevils per plant, which is considered the optimal control threshold as laboratory studies show that damage by five adult weevils can kill a medium sized plant in about 10 days (Gopal, 1987). This threshold is reported to have been surpassed when the combined mean number of weevils per plant in Kisumu, Nyakach, Kendu and Homa bays was estimated as six (Ochiel *et. al.* 2001). By 1999 however,

seemingly after weevil attack, the weed occupied an estimated 3,500 hectares on the Kenyan side of the lake down from around 6,000 hectares before introduction of *Neochetina* weevils (Mailu, 1999). These examples show that although biological control of water-weeds is a relatively slow management strategy, its long-term benefit in monetary terms and environmental safety though incalculable are beyond doubt.

In related studies, the development of mycoherbicides for use as control agents is still in its initial phases since some pathogenic fungi such as *Alternaria sp*, *Fusarium sp*, *Myrotherium sp*, *Curvularia sp* and *Phoma sp* have been identified to be associated with diseased water hyacinth (Kusewa, *et.al.* 2000). However, some technicalities such as the minimum 10 hours of dew necessary to enable fungal pathogens (reared *in vitro* and applied as foliar spray) to germinate, infect, and colonise the weed (Shabana, *et.al.* 2001) may need to be resolved before mycoherbicides can become viable control alternatives.

1.4.2 Physical control

Alongside the classical biological control option, mechanical or manual control of the weed through the use of machines and hand held implements especially in more sensitive areas such as fish landing beaches, water intake points and dam-sites have been used e.g. at the Owen Falls dam in Jinja. Mechanical removal harvested about 3,000 tons of hyacinth each day at Jinja (Ochiel, pers. comm.). Other available physical methods of control are the building of booms, burning, flow manipulation, laser radiation and ultrasound, but the latter two are still to be developed into practical and potent control methods. Physical control has got obvious scale limitations while mechanically removed hyacinth may encourage secondary infestation from remnant plant fragments if the necessary precautions are not taken to avoid such instances⁹. Manual control is limited to the banks that are immediately accessible to those pulling out the weed leaving the open expanses of water inoperable as far as these tools are concerned. Cost estimates reveal that a single manual removal of *Eichhornia* and *Pistia* from small water bodies in India could be around 150 and 75 rupees ha⁻¹ respectively while the cost of *Eichhornia* in a large water body could cost up to 437 rupees¹⁰ (Wade, 1990). Implementing physical control may not be as cheap as biological control since the recurrent costs of biological control may taper off to almost zero with time while those of physical control remain constant if not increase with the passage of time.

1.4.3 Chemical control

Control of water hyacinth through chemical applications is another method that can and has been used in other parts of the world. However, this option is not always the most effective since there is always the danger of new reinfestations emerging from the seeds of the plant. Fish are also not able to respond rapidly to changes, resulting from weed control especially if such changes are abrupt hence, fishermen often regard mechanical and possibly

⁹ Although the practicality of this prevention still remains in doubt.

¹⁰ Approximately 1.5 rupees per 6 man hours.

chemical weed control as deleterious to their fishery. Chemical control has its strong and weak points. The use of such a method however has often been approached with apprehension due to possible negative human and environmental effects. Another complication arises considering the fact that for it to be used in one country on a shared resource such as L. Victoria, it is imperative that a joint agreement between all countries sharing the entire Nile basin is entered. The herbicides 2,4-D and Glyphosate can be used but since they can kill the weeds fast, the huge mass of dead plant material can lead to the deoxygenation of lake water with consequent fish kills. This may replace the otherwise beneficial aspects of weed control with undesirable effects due to concomitant fish kills. Herbicides and mechanical removal, the primary means to fight the weed in the United States have proven expensive and ineffective (ENN, 2000).

1.5 Problem statement and major goals

Lake Victoria is currently under the threat of water hyacinth (*Eichhornia crassipes*), which is arguably the world's most dreaded aquatic weed. The weed since reported present in the lake has caused untold havoc to the riparian communities. Its adverse effects include *inter alia*, possible interference with water-based transport, fishing, hydro electricity generation, increases in disease vector incidence and arguably, an erosion of the lake's spectacular beauty. However, these reports do not appear to lend much concern to the much larger rural population, which studies have shown to be poorer and more vulnerable to adverse environmental stresses.

It is argued that the poor are usually the greatest victims of environmental stresses and this study adopts this view and will try to assess the truth of this statement. The present study aims at identifying whether the water hyacinth has adverse welfare impacts on the households residing at the Kenyan shores of Lake Victoria. Specifically, this will involve determining whether or not water hyacinth has an impact on the welfare levels of households resident at the shores of Lake Victoria and whether this impact differs with socio-economic status. In the interim, it is postulated that the water hyacinth has negative impacts on the welfare of households of the Lake Victoria shores and that the poorer the household, the greater this negative effect on its welfare will be.

1.6 Justification

There exists a vast amount of research literature about Lake Victoria—fish species, plants and micro-organisms, ecosystems diversity as well as fisheries related socio-economics (Okeyo-Owuor, 1999)¹¹. However, quantification of the costs of water hyacinth to society or even specifically to the rural community has not been done. This missing information has been succinctly stated in several forums and the consequences of its absence highlighted (see for example Greathead and de Groot, 1993).

Most of the existing studies that have attempted to assess the impacts of the water hyacinth have been at best attempts to estimate partial effects i.e. on sub populations e.g. fishermen or urban dwelling populations. This can bias

¹¹ But little or inadequate work on the socio-economic impacts of the water hyacinth.

the results to an extent of giving virtually no weight to the effects of the hyacinth accruing to rural populations, if not impairing generalisations. The fact that most of the human population around the lake is rural strongly suggests that this is an important segment that has not been represented in the results and consequently can easily be quiet sufferers of biased decisions made therefrom. If we assume for expositional purposes that the hyacinth affects urban dwellers quite differently from the way it affects rural dwellers, we could rightly assume that the unknown but possibly opposing effects of the hyacinth on rural dwellers are assumed away. This is possible because policy and political expedience go hand in hand, and it is also true that urban populations more often hold a lot of political clout due to their role as opinion shapers. This forces moral and ethical questions about decisions made from these partial analyses and their concomitant policy prescriptions.

Secondly, there has been little attempt to consistently determine through a theoretical and empirical link the effects on welfare experienced by households residing close to the lake after its invasion by water hyacinth. A likely result is that, conclusions drawn therefrom are based on spurious correlations between observed phenomena. Studies of this type have in most part been scarce and whenever adverse effects are mentioned, they are scantily covered in precise quantitative proof. Even if such studies were done elsewhere, it may become difficult to compare these results with the case of Lake Victoria since such studies have been undertaken under different conditions.

While some reports view the water hyacinth's presence as partially advantageous, the fraction of the community holding this opinion is unknown. It is possible that overall, even with a resurgence of nearly extinct fish species, household welfare generally has not improved in a degree commensurate with the negative impacts that the water hyacinth may cause. It would be helpful to know if the hyacinth does indeed have positive aspects to a section or sections of the community and if it does, how these compare to the cost of water hyacinth to the wider community. This information would go a long way in helping make water hyacinth control related decisions since lack of such information impairs the ability of governments and donor agencies in making appropriate investment decisions on weed control. It also impairs an assessment of the impact of control implementation as well as impairing assessments of the economic returns to the marginal costs of ongoing control measures (Hill *et al*, 1997). With such information such as knowing which sections of the community are impacted and whether this impact is positive or otherwise, it becomes possible for both the government and NGOs working in these areas to avoid *ad hoc* decisions and therefore enable prioritisation in a view of providing appropriate assistance to the residents. This may hopefully also improve the ability to shift from a reactive to a pre-emptive mode of environmental policymaking.

As it is expensive to undertake hyacinth control, given the presence of potentially equally competitive areas for government spending, some means of priority ranking should be sought. It is therefore not only financially

prudent to allocate available funds in an optimal manner, but also ethically justifiable to target control in such a way that most control effort is directed where the adverse effects are greatest. This is indeed one of the canons of public expenditure—targeting public expenditure where most needed with a view of income redistribution.

1.7 Study Objectives

The present study aims at examining the welfare impact of the water hyacinth (*Eichhornia crassipes*) on the rural households living at the Kenyan Shores of Lake Victoria. Specifically, this study attempts to answer three related questions *viz*;

- (i) Is there a welfare impact on households following water hyacinth invasion?
- (ii) What is the nature of this impact? Is it positive or negative?
- (iii) Is this impact greater for poorer households?

1.8 Study Hypotheses

Is there a problem? Most studies on the impact of natural environmental disasters indicate that environmental disasters usually have deleterious effects on the livelihoods of those people residing in the disaster areas. The water hyacinth is hypothesised to be such a disaster. It is therefore hypothesised that the water hyacinth has negative impacts on the welfare of rural households of the Lake Victoria shores. This is a question of efficiency aimed at answering the question whether the hyacinth is indeed deleterious to household welfare or not and this is can be seen to answer a first line question asked by policy makers during policy formulation (what).

The hypotheses can be stated in null form thus;

H₀: The water hyacinth does not have a negative impact on household welfare

Is it a general problem? A second hypothesis is that the poor have a limited adaptation to such environmental risks or shocks, and therefore, it is hypothesised that the poorer households along the lake Victoria shores are affected more significantly by the water hyacinth, than are more wealthier households. It is argued that the wealthy households can insulate themselves much more effectively from income fluctuations than the poor can. This on the other hand is a question of equity. Do certain classes suffer more heavily in the presence of environmental shocks? The answer to this question which is one of the basic questions in economic enquiry is important in formulating policy recommendations.

The hypotheses can be stated in null form thus;

H₀: The water hyacinth does not have a greater impact on household welfare for poor households than for non poor households

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

This chapter reviews work related to the current problem of water hyacinth in Lake Victoria and tries to create a link between the different bits of information. It begins by a general description of the relationship between the environment and welfare and goes further to state the proximate pathways through which these two interact. A section is devoted to the opposing ideas with respect to the water hyacinth and its usefulness as well as its disadvantages. Work relating to poverty assessments, their measurement and related literature is also reviewed. The later sections are devoted more to the linking of conceptual and empirical approaches to the measurement of welfare and how these can be borrowed to suit the current work. The description about the exact links between welfare and the environment—specifically water hyacinth—are general at best owing to the lack of comparable welfare assessments that link the two hence, poverty at times is likened to welfare although technically, these two concepts are quite distinct.

2.2 Environment and Welfare Linkages

The evidence of human poverty and deprivation in the world is unmistakable, as is the evidence of the worsening environmental conditions caused by and contributing to poverty. The toll on natural resources takes many forms, including among others, soil erosion, loss in soil fertility, desertification, deforestation, depleted game and fish stocks from overhunting and overfishing, loss of natural habitats and of species, depletion of groundwater resources and pollution of rivers and other water bodies. This degradation further exacerbates poverty and threatens not only the economic prospects of further generations, but also the livelihoods and well being of current populations (WRI, 1992). It is also important to keep in mind that the poor are both victims and agents of environmental damage and rely on resources that they have little or no legal control over (World Bank, 1992). There is a link between environmental quality and welfare since in every closed system, what happens in one part of the ecosystem has ripple effects in other parts of the system. The Lake Victoria basin in sub Saharan Africa is no different from many parts of the developing world, where much of the human population relies directly on the environment for its livelihood. The combination of this close dependence on the natural resource base and the fragility of the interconnections between them serves to explain why natural resource management is important in the developing world (Pearce and Turner, 1990).

Poverty is caused by the lack of income and assets necessary to attain basic necessities, a sense of voicelessness and powerlessness as well as vulnerability to adverse shocks, which are linked to an inability to cope with environmental and other stresses (Chambers, 1983, Glewwe and Hall, 1995). From a participatory poverty assessment in Kenya, the problem of food adequacy was identified as the major problem and a characteristic of poverty and the water hyacinth was described as being responsible for poverty

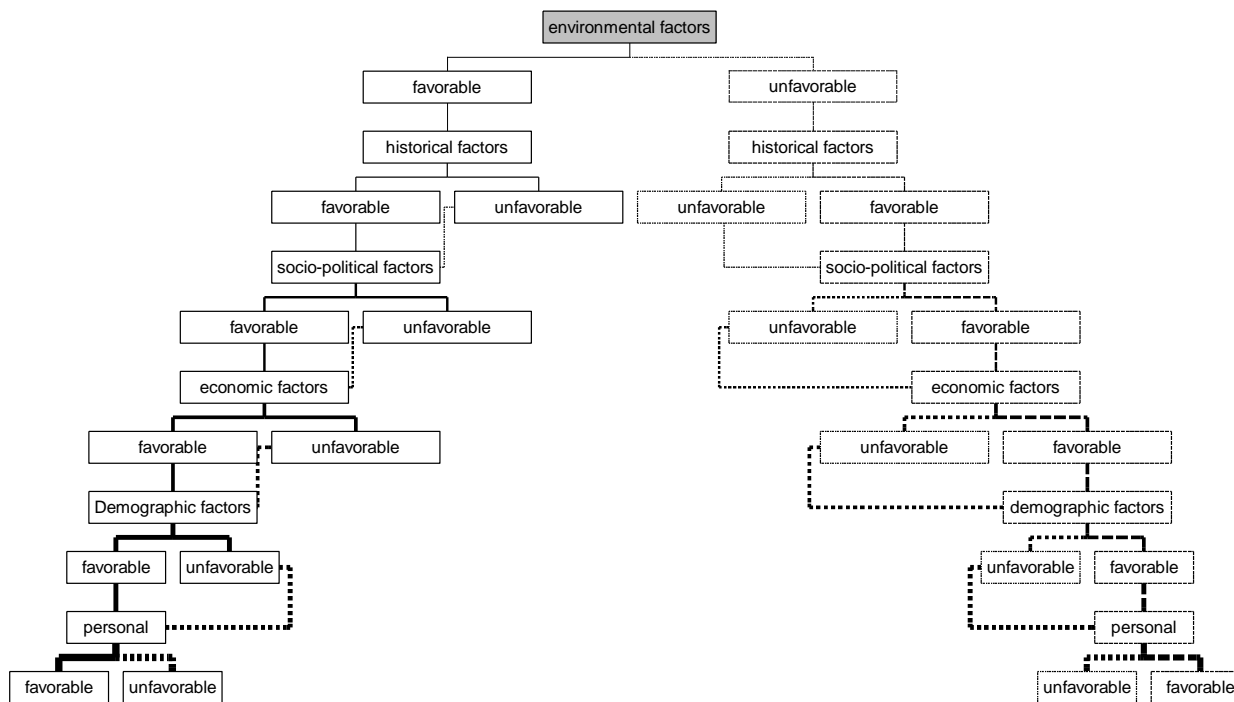
(Republic of Kenya, 1997). The most difficult period of the year for the poor was identified as between December and May when food stocks, employment opportunities and income are at their lowest (Narayan and Nyamwaya, 1995). Besides, the lakeshore inhabitants are described as being among the most food insecure in Kenya (Abila, 1998).

Poverty and lagging development serve to amplify the adverse effects of natural disasters (World Bank, 2001). Environmental disasters also disrupt natural physical and social assets of poor households and the few studies that have analysed the impact of natural disasters on poverty show that harm to current and future living standards can be significant (*ibid*). These shocks accrue to individuals, households or entire communities or even whole villages. By their indiscriminate nature, natural disasters such as pest and disease attacks are not idiosyncratic risks but covariant and are difficult to insure against since they affect everyone in the vicinity although the strength of the resulting impact on individuals may depend on their ability to adapt to the changes. This adaptation depends on whether they have the capacity to weather the impacts.

Techniques used in the measurement the impacts of such environmental shocks have been developed but still come under criticism for some of their shortcomings. However, rather than the pushing for their further theoretical refinements, the use of environmental valuation concepts and their application to practical problems is strongly advocated. This is because a major purpose of valuation exercises is not to provide fine tuned numbers but to indicate broad orders of magnitude (Munasinghe and Lutz, 1993). The linkages between household welfare and the environment are complex and therefore, the modelling of these links requires a holistic approach that looks at all the routes that link welfare to the environment (Munasinghe and Lutz, 1993). Figure 2.1 traces the proximate pathways through which the environment and other determinants of welfare interact¹².

¹² Adapted with modification from a 1997 poverty assessment report prepared for the Government of Kenya by AMREF and the HRSSD—OVP/MPND.

Figure 2: 1 The environment and welfare interaction



Source: GOK, 1997 The Second Participatory Poverty Assessment Study--Kenya.

The causes of poverty (read welfare) mentioned during an interactive (participatory poverty appraisal) in Kenya--1997). Among the *historical* factors mentioned were evictions, *Demographic* high level of dependence, reluctance to practice family planning, *Environmental* Drought and lack of irrigation water, crop failure as a result of climatic unreliability, wildlife menace, floods, water hyacinth in fresh waters especially Lake Victoria, livestock diseases, *Economic* Unemployment, High cost of living, corruption, over-reliance on cash crops, poor extension services at all levels and sectors, slow industrial sector growth, landlessness *personal*, laziness, social breakdown, *political* ethnic clashes, insecurity in urban as well as rural areas.

2.3 Ecosystems and Invasions by Exotic Species

No ecosystem is immune to the threat of invasive species which crowd out native plants and animals, degrade habitats and contaminate the gene pools of indigenous species (WRI 2000). The biodiversity of freshwater ecosystems is much more threatened than that of terrestrial ecosystems and about 20 percent of the world's freshwater fish species have become extinct, threatened or endangered (*ibid.*). Physical alteration, habitat loss and degradation, water withdrawal, overexploitation, pollution and the introduction of non-native species all contribute to the decline in freshwater species (WRI, 1992; WRI 2000). During the 1996 UN-Norway Conference on Alien Species, it was concluded that invasive species like the water hyacinth constituted a threat to biological diversity conservation worldwide, second only to habitat destruction (Hill, Waage and Phiri 1997; USGS 1999).

There exist many examples that show the damages that can be associated with the invasion of ecosystems by exotic species. For example, in North America, introduced species have played a large role in the extinction of 68 percent of the fish in the past 100 years (Miller 1989). Leidy's Comb Jellyfish, native to the Atlantic coast of the Americas was accidentally introduced in the Black Sea where it has nearly wiped out the fishery (Travis 1993). The Zebra mussel, a native of the Caspian Sea was dumped into the US' Great Lakes in the late 1980s and since then, control attempts have cost local industry an estimated US\$ 3-5 billion (Bright, 1998). The Asian tiger mosquito, a potential transmitter of 18 viral pathogens, one of them, the West Nile virus, suggested to be more deadly to North American bird species than to species in Africa, the Middle East and Europe where the virus is normally found is spreading rapidly worldwide (USGS, 1999). Closer home, in Lake Victoria, by 1983, Nile perch, an introduced species made up almost 70 percent of the catch. Nile Tilapia and a native species of sardine made up most of the balance—the former two species having been brought into the lake from other areas to boost production (Achieng, 1990; Geheb and Binns, 1997). For the local communities that had depended on the native fish for many decades but did not benefit from the success of the Nile perch fishery¹³, the local availability of fish for consumption has declined (Kaufman, 1992; Wilson *et.al.*, 1999). Drying of the Perch's oily flesh to preserve it requires firewood, unlike the cichlids it replaced, which could be air dried and this has increased the pressure on the areas limited forests, increasing siltation and eutrophication which in turn has further unstabilised the ecosystem (Kaufman, 1992; Geheb, 1997; Roach, 1999).

2.3.1 Water hyacinth -Physical attributes

An appropriate definition of an aquatic weed is 'an aquatic plant which when growing in abundance, is not desired by the manager of its place of occurrence' (Pieterse, 1990). Water hyacinth fits in to this description and hence deserves to be called an aquatic weed. Water hyacinth is the common name of a free-floating fresh water perennial tropical herb, *Eichhornia crassipes*. It is 90 percent water and has many air chambers that enable the

¹³ Partly because most catch of Nile Perch and Nile Tilapia is shipped out of the region and that, the catch of these species is dependent on gear which local fishermen can hardly afford.

plant to float on the water. The weed beautiful from its look has been given many names "beautiful devil", "pest and terror". It is a free floating plant with a thick rhizome and long, purple feathery roots which hang free in deep water or anchor the plant to the mud in the shallows (Ivens, 1982). The roots are adventitious, unbranched, darkly pigmented ending in a conspicuous root cap and may extend to 3 metres (Gopal, 1987). Daughter plants are produced at the ends of runners. It spreads by stolons, which develop at the base of the rosette and under optimum conditions doubles its progeny in 6-15 days (Bakar, *et.al*, 1984; Anon, 1996b). Three plants may produce 3,000 new plants in 50 days (Aston, 1973) or 140 million plants every year, enough to cover 140 hectares with a fresh weight of 28,000 tonnes (Otieno and Wangila 1993). In the Congo, two plants have been observed to produce 1200 daughter plants in four months, and in a really dense infestation, the mass of vegetation can be thick enough to support the weight of a man. The smooth fleshy leaves are bright green and arranged in rosettes with a swollen stalk, 2-12 inches long (up to 3 feet long when growing densely under hot, humid conditions) and a broad pointed blade.

The bisexual flowers are lilac to lavender with a central yellow area, borne on a single spike. After flowering, the inflorescence bends down into the water and from seed capsules containing up to 300-400 seeds emerge small long-lived seeds that sink to the bottom upon release (Ivens, 1982; Harley, 1994; Harley, 1997). These seeds can survive in mud for 30 years, posing severe reinfestation problems in cleared areas (Otieno and Wangila 1993). It however is not clear whether fertile seed is set under East African conditions (Ivens, 1982).

The weed encourages evaporation by a factor of 3-5 times that of open water through water hyacinth enhanced evapotranspiration (Hamdoun *et.al*. 1977; Otieno and Wangila 1993). The free floating habit of water hyacinth suggests that its growth is not affected by water depth and seasonal changes in water level but it is noted to thrive on muddy shores where its roots can anchor. Environmental factors such as water depth, water level changes, light intensity, temperature, pH, and nutrients have effects on the proliferation and growth of the water hyacinth (Gopal, 1987). The occurrence of the weed almost exclusively between latitudes 40°N and 35°S serves to amplify the importance of temperature and therefore geographic position in its spread.

2.3.2 Origins and spread

Its native home is in the Amazon from where it has spread throughout tropical, subtropical and warm climates. It belongs to the family pontederiaceae, first described by C.F.P Von Martius, a great explorer of tropical South America in 1824 (Gopal, 1987). It reached botanical gardens in Europe even before it was formally christened by von Martius since von Humboldt another famous explorer had collected the water hyacinth from the banks of River Cauca in present day Colombia in 1801 (*ibid*). The family pontederiaceae is widely distributed throughout the world, and is nearly

cosmopolitan today due to introduction by man¹⁴. Taking advantage of its free floating habit, rapid vegetative growth and the ability to survive on mud during periods of low lake water levels, it has naturalised in a wide variety of aquatic habitats.

The water hyacinth was introduced into USA from South America at the 1884 cotton states exposition in New Orleans for its decorative lavender flowers. Since it infests a wide range of freshwater habitats—lakes, rivers, canals, swamps—and it has now spread throughout a large portion of the southern USA particularly the Southeast. By 1995, the water hyacinth was reported present in over 59 countries worldwide (Anon, 1996b). Some of the earliest introductions in Africa have been reported in Egypt during the reign of Khedive Twafiq (1879-1892) ostensibly to be planted in a public garden (Gopal, 1987). It was until the 1930s confined to canals and lakes in the vicinity of Cairo, Alexandria, Damanshour, Damietta and Bilbis (Tackholm and Dar 1950). It has since been a pest, everywhere in the Nile delta and since 1972 its southwards spread has been facilitated by the slowed river flow after the construction of the Aswan high dam (Obeid, 1975). The weed's introduction into the Congo river in 1942 saw its establishment by 1956 and it is believed to have spread into the Nile basin through an interconnective swampy area in South-western Sudan (Bebawi, 1972) and this is a likely route it took before finding itself into L. Kyoga and more recently L. Victoria (Woomer, 1997). In southern Africa, it is now distributed in the eastern half of South Africa. The next introduction in Zaire (now the Democratic Republic of Congo) in 1950-51 saw it become a serious impediment to navigation and fishing and herbicidal sprays of 2,4-D could not fully contain its spread (Gopal, 1987).

Previously unknown to the lake inhabitants, it is suspected that it entered Lake Victoria through river Kagera (Thompson, 1991) whose upper tributaries, R. Mukungwa and R. Nyabarongo were reportedly infested with water hyacinth for an entire length of over 500 km (Bugaari, *et.al*, 1998). Estimates made between April and August 1999 indicated that 3.5 hectares of weed flowed every week into the lake from this river (Twongo *et.al*. 1995) with other estimates of daily rates ranging between 0.2 ha and more than 1.5 ha/day depending on seasonal flow (Moorhouse *et.al*. 2001). Earlier reports indicate that the weed had already been spotted in Lakes Naivasha (Njoka, 1988), L. Kyoga in 1987 and River Pangani in Tanzania (Ogwang and Molo, 1997). In the case of L. Victoria, it was first reported on the Ugandan side of the lake in 1990 although it has been grown as an ornamental plant in East Africa since the 1950s. In East Africa, although present in ponds and dams for some time, the first place where *Eichhornia* was observed to have gone out of hand was on the Sigi river, near Tanga in Tanzania in 1955 (Ivens, 1982). In 1959, it also appeared on the nearby Pangani River in the neighbourhood of Korogwe and spread rapidly downstream (*ibid*). The weed occurs in other parts of West Africa such as Nigeria, Senegal, Niger, Benin and Ghana. It has also been reported in other countries *viz.* Zimbabwe,

¹⁴ The first use of the plant was its flowers explaining its rapid spread as it was/is a valued aquarium plant particularly in Europe.

Angola, Mozambique, Madagascar, Central African Republic, Uganda, Tanzania, Zanzibar, Mauritius, Reunion, Rwanda and many other areas.

Just as other of mans activities when introducing exotic species, water hyacinth importation was not supplemented by the introduction of the plant's native enemies. This is what makes the weed survive almost unhindered, in Lake Victoria as well as in similar occasions of water hyacinth infestation. In addition, ICRAF scientists through satellite remote sensing technology had uncovered a source of nutrients that they claimed allowed the water hyacinth to grow out of control in the lake (Roach, 1999).

2.3.3. Legal aspects of the cross border spread of diseases, pests and weeds

Inland waters are usually divided by boundaries resulting in a variety of regulatory schemes that are influenced by factors other than environmental. In such circumstances, the number of treaties devoted exclusively to the protection of inland waters from pollution is relatively insignificant (Boes, 1992). The regulation and control of weed spread are complicated by the modes of invasion. Some species find their way into new habitats by accident—they hitchhike in ships, planes, on traded goods or travellers, while others are intentionally introduced for hunting, fishing or pest control. Others 'escape' their intended confines like the seaweed *Caulerpa taxifolia*, which was originally intended for aquariums in Europe but escaped and is now a common site along French and Italian coastlines (MCBI, 1998). The same can be said about the water hyacinth since some believe that soldiers returning home carried it as a souvenir and it found itself in East Africa. Regulating the spread of the water hyacinth is therefore made difficult due to its mode of spread, a mixture of intentional and unintentional or accidental channels. As part of a larger campaign against the weed, as well as other environmental problems, the Kenyan parliament adopted in December of 1999 The Environmental Management and Coordination Act (No. 8 of 1999) (Republic of Kenya, 1999) which states in part;

"..No person shall, without prior written approval of the Director General given after an environmental impact assessment in relation to a river, lake or wetland in Kenya carry out any of the following... (c) introduce any animal whether alien or indigenous in a lake, river or wetland (d) introduce or plant any part of a plant specimen whether alien or indigenous, dead or alive in any river, lake or wetland....."

part V [protection and conservation of the environment] section 42 (1).

This act received presidential assent on January 6, 2000 and came into effect a week later on January 14, 2000. Unlike other pests and diseases the spread of water hyacinth is uncontrolled by way of international co-operation to curb its spread. Some multilateral treaties exist, which in a way can help contain the spread noxious weeds but on careful examination, the weeds that the treaties relate are mostly those that compete with agricultural crops. The International Plant Protection Convention [Rome 1951] is probably one of the earliest examples of enactment designed as part of an attempt to limit the transboundary spread of undesirable pests and diseases. Its objective is to

maintain and increase international co-operation in controlling pests and diseases of plants and plant products, and in preventing their introduction and spread across national boundaries. Among the provisions to this convention was for states to inspect areas under cultivation, consignments in international traffic for existence of outbreaks of plant pests and diseases. In 1959 an agreement concerning co-operation in the quarantine of plants and their protection from pests and diseases was signed in Sofia. Its objective was to expand co-operation in the quarantine of plants and their protection from pests, diseases and weeds and to co-ordinate measures aimed at quarantine, pest and disease and weed control. The signatories to this agreement included Albania, Bulgaria, Czechoslovakia, Democratic Peoples Republic of Korea, German Democratic Republic, Hungary, Mongolia, Poland, Romania, and USSR. Under the agreement, parties were to take necessary measures against a list of pests, weeds and diseases¹⁵, exchange information concerning pests and diseases as well as their control¹⁶, provide technical assistance¹⁷ and co-operate in applying uniform phytosanitary regulations for import or export of plant matter from one country to another¹⁸. The phytosanitary convention for Africa, South of the Sahara¹⁹ adopted in 1954 is another example of international co-operation in combating crossborder spread. It's objective was to prevent the introduction of diseases, insect pests and other enemies of plants into any part of Africa south of the Sahara, to eradicate or control them in so far as they are present in the area and to prevent their spread. The African convention on the conservation of nature and natural resources [Algiers, 1968] aimed at undertaking an individual and joint action for the conservation, utilization and development of soil, water, flora and faunal resources for the present and future welfare of mankind, from an economic, nutritional, scientific, educational, cultural and aesthetic point of view (Kiss, 1983). Looked at closely, these agreements are somewhat general or even quiescent in the prevention of the spread of waterweeds²⁰.

2.4 Different opinions of the water hyacinth

2.4.1 Adverse impacts of water hyacinth

The presence of the hyacinth has a profound socio-economic and ecological impact where it strikes. These effects include *inter alia* interrupted fishing activity, water supply and HEP generation, increase in the incidence of disease vectors, loss of biodiversity, increased eutrophication—referred to as cultural eutrophication (UNEP, 1993), deoxygenation and the erosion of the lake's scenic beauty (Harley *et.al*, 1997). In Malaysia, reports indicate that the weed had other problems associated with it which include *inter alia*, the impediment of water flow, increased siltation and subsequent clogging of

¹⁵ Listed in Annex (Article I). **NB:** *Eichhornia crassipes* was not among the list of principle quarantinable pests diseases and noxious weeds probably because these Eastern European countries fall in climatic zones where the hyacinth cannot proliferate in the wild due to the high latitudes.

¹⁶ Article II

¹⁷ Article III

¹⁸ Article IV

¹⁹ Kenya is the only East African State that had not ratified the convention.

²⁰ For instance, there are about 10 agreements dealing with consumptive use of the waters of Lake Victoria and those prior to World War I show Britain as the contracting party (Okidi, 1990) but there seem to be none specifically aimed at controlling the spread of water weeds.

irrigation canals and drains, rivers and other waterways, water loss through evapotranspiration and interference with fishing and culture (Bakar *et.al.* 1984). Other activities such as waterbased transport on the lake can be crippled by the weeds' presence (Bugaari, *et.al.*, 2001).

Among plants that 'fall into pieces' as they grow, water hyacinth is one of the extreme examples in which, whole ponds, lakes or rivers may be filled with the separate and independent parts produced by a single zygote (Begon, Harper and Townsend 1990). As large quantities of dead plant material accumulate in the water bottom, the oxygen concentration of the water deteriorates and can cause massive fish kills. Gradual siltation can be encouraged as conditions under water hyacinth mats makes decomposition of organic matter slow and the development of mats may finally result in the disappearance of a small water body (Gopal, 1987).

The aquatic environment is an essential habitat to many life forms, including various insect genera and genera of aquatic or amphibious snails that play a role in the transmission of human disease. The presence thus of aquatic weeds, in particular, *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia molesta* greatly enhances the potential of this habitat for the propagation of disease vectors and parasite intermediate hosts that transmit cholera, bilhazia and schistosomiasis (Bos, 1997). Water hyacinth thus provides an ideal breeding ground for mosquitoes, insects and snails, which play a vital role in disease spread (Otieno and Wangila 1993; Msambichaka, 1995; Bugaari, *et.al.*, 1998; Mailu 1999; FAO, 2000). The diseases in question are among those that cause major public health problems in tropical countries including Kenya and they include *inter alia*; malaria, schistosomiasis and lymphatic filiasis of the brughian type, the latter almost exclusively being linked to the presence of aquatic weeds (Bos, 1997)²¹. It is worth noting that in sub Saharan Africa, contaminated drinking water and poor sanitation contribute to infectious and parasitic diseases that account for over 62% of all deaths, twice the level in Latin America and twelve times the level in industrialised countries (World Bank, 1992).

A clear example of the adverse impacts of the water hyacinth is in the case of Papua New Guinea. On the Sepik river system, a major waterway in PNG, water hyacinth was first reported in the Lower Sepik River floodplain in 1984 and spread quickly, infesting many lagoons and hundreds of kilometres of riverbanks. By 1991, large infestations were severely disrupting the lifestyle of villagers from the middle and lower Sepik who could only reach gardens, markets and fishing grounds via the waterways (Harley *et al.* 1997; CSIRO, 1998). It is reported to have had serious deleterious effects on the socio-economic livelihood and environment of the communities living close to the waters infested by the weed (Harley, Jullien and Wright 1997). People died due to the combined effects of reduced nutrition, degraded water, increased disease vectors and generally reduced health which is directly related to water hyacinth degradation of the environment (Harley, *et.al.*, 1997, CSIRO, 1998). These infestations also resulted in the deaths of people who could not

²¹ Responsible for a minor share of lymphatic filiaiasis, restricted to South Asia.

reach essential services in time for life saving treatments. In another dimension, water hyacinth control necessitated by the weeds presence means that resources are diverted from other expenditure sectors such as health provision etc.

In Lake Victoria, the situation did not appear to be very different as incomes from fishing in Dunga and Nyakach beaches were reported to have declined due to the effects of water hyacinth through a decline in fishing days (Okallo, 1999). Fishermen complained that whenever the weed attacked, they were unable to access their fishing grounds since the weed choked the landing site to an extent that no boat could leave nor land at the beach. In Zimbabwe, there was a 30 percent decline in fish catch due to water hyacinth infestation. Catches which were as high as 50-60 kg per day could even drop to virtually zero (Chikwenhere and Phiri, 1999). Similarly in West Africa, fishermen recorded losses due to the spoliage of fish as the time it took to dock was lengthened by the presence of water hyacinth mats. In addition, fuel usage was heightened due to the extra work demanded of their boat engines to move through the hyacinth and this extra cost was passed on to the consumers in the form of higher fish prices (FAO, 2000). In Uganda, a preliminary assessment showed that Uganda shillings 6.16 Billion worth of fish sales was lost in three landing beaches (Masese, Gaba and Kasenyi) due to the presence of water hyacinth. In addition, fishing nets worth Uganda shillings 233.9 million were lost to the weed mass. There was also an increase of Uganda shillings 7.5 million worth of fuel per fishing trip all totalling to Ush 6.481 Billion loss between 1994 and 1995 for up to 60 fishermen (Nkuba, 1997).

This potentially threatens the fishery in Kenya since the lake offers 90 percent of the total fish landed in the country (Ogutu, 1988; Geheb, 1990; Republic of Kenya, 1998) and employs directly most of the 34,000²² fishermen estimated in Kenya while supporting 798,000 people (Bokera and Ikiara, 2000). A continuous decline in fish production from Lake Victoria in the recent past has been attributed partially to the spread of water hyacinth (Republic of Kenya, 1998).

The cost of water hyacinth infestation is estimated to be in the order of billions of dollars and the estimated 40,000 hectares of weed in 1999 on the lake were feared to affect more than 40 million people in the three riparian countries (Mailu, 1999)²³. For instance, water hyacinth infested River Nile cost the Sudanese economy an estimated Sudanese pounds 6.8 million (US\$ 19.12 million) worth of control effort over a 15 year period (Obeid, 1975). A fleet of 42 boats and 3 aircraft and 3 stations were used in 1963 on the Nile by the Sudanese Ministry of Agriculture to maintain access for commercial steamers and an additional 500,000 pounds in additional repairs and maintenance (Pieterse, 1990). The treat of biodiversity loss caused by water

²² For instance, Geheb *et. al.* (1997) estimates over 90,300 fishermen operating in the Kenyan sector, implying that different estimates may arise depending on who a fisherman is defined to be by different authors.

²³ Media reports indicated a 70% drop in economic activity in Kisumu due to blockages by water hyacinth.

hyacinth though immediately incalculable is another issue to contend with (Hill, Waage and Phiri, 1997).

2.4.2 Uses of the water hyacinth

Aquatic weeds as opposed to terrestrial weeds that compete with agricultural crops are unwanted mainly because they hamper the often multifunctional uses of water bodies. In low densities however, these plants are often beneficial to the aquatic ecosystem since they provide oxygen, purify the water by trapping silt particles, take up oxygen compounds or support associated populations of micro-organisms and also provide habitat for fish fry and other organisms.

The first use of water hyacinth was probably its beautiful flowers. The leaves, petioles and inflorescences can be steamed, fried or cooked and eaten as in Java and Philippines (Gopal, 1987). In Bangladesh where people have lived with the water hyacinth for many years, they have discovered that the weed has some value. With MCC (Mennonite Central Committee) assistance, a number of Bangladeshi groups have established themselves as successful businesses, manufacturing marketable products such as paper and furniture using fibres extracted from the water hyacinth plant. For those employed in these activities, water hyacinth has become a resource basic to their livelihood. In Kenya, the Kisumu Innovation Centre Kenya (KICK) had succeeded in developing an impressive range of paper and furniture prototypes using Bangladeshi information. Innovative uses of the weed can as well provide as an income source for the unemployed (Daily Nation, 5 May 2001). For instance, a Kenyan woman who designed handicraft made from the hyacinth won the United Nations International Womens Fund (unifem) Innovation award (2000). In the Philippines, Thailand and Indonesia, petioles are often used to make different articles like baskets, floor mats, glass mats handbags, ice chests, vases, hats, ropes, shoe soles or as stuffing for upholstery or even fish traps and in other areas, it has been tried in the manufacture of paper and boards (Gopal, 1987).

The weed can also be utilised as animal feed for pigs—as in China, Thailand, Malaysia, Indonesia and India (Gopal, 1987; FAO, 2000; Lindsey *et al.*, 2000). Fresh leaves are sometimes eaten when other feeds are scarce, but normally more than 25% fresh water hyacinth in the food reduces intake and there is also great danger of spreading the weed through faeces. A common formula however is 40 kg of water hyacinth, 15 kg of rice bran, 2.5 kg of fishmeal and 5 kg of coconut meal (FAO, 2000). In the making of silage, molasses can be added and the addition of Sodium Chloride and Urea increases the nutritive value and quality of silage. Silage with a 4:1 hyacinth:rice bran ratio has been attempted with good results (*ibid*). Research conducted by the Louisiana State University Agricultural Experiment Station in collaboration with NSTL involved feeding chopped, solar-dried water hyacinths to a herd of dairy cows for four weeks. It was found that the cows produced as much milk and of comparable quality as did cows fed on their customary hay ration (NASA, 1996). The weed has potential real economic value and it has been reported for instance that the

weed can be used to produce biogas energy, purify water contaminated by raw sewage, produce manure and produce a substratum for the nourishment and breeding of some fish species (Ikiara, 1999).

While others have tried to use the weed as a source of fibre in making handcrafts, there have been unsubstantiated claims that the presence of water hyacinth in Lake Victoria was accompanied the resurgence of otherwise near extinct fish species²⁴. These include the 'kamongo' and 'mumi' (mudfish and lungfish) which thrive best hidden under shallow marshes close to the shores. These are ostensibly the conditions that are created by water hyacinth. These are however, assertions that should be subjected to critical study to authenticate them.

If grown in water with a high concentration of mineral salts, (e.g. in domestic and industrial sewage lagoons and irrigation channels), water hyacinth can absorb these dissolved salts and the degree of contamination of the water to be released into the lake can be greatly reduced. Under favourable conditions, one acre of water hyacinth can remove 22-44 kg of Nitrogen, the same amount of Potassium, 18-43 kg of Sodium, 11-22kg of Calcium and 2-4kg of Magnesium per day from polluted effluent. Similarly, one hectare of water hyacinth can also remove heavy metals *viz.* 89g of Mercury, 104g of Lead, 297g of Nickel, 321g of Strontium, 343g of Cobalt, 385g of Silver and 298g of Calcium plus 2,134g of Petrol and other organic compounds per day. Scientists from NASA have attempted to use water hyacinth for biological purification of polluted effluent with great success (Hassan, 1979; NASA, 1996). However, primary (physical) and secondary (biological) treatment of sewage may remove 35% and 85% of pollutants respectively and remove 30% of the Phosphorous, 50% of the Nitrogen and 70% of the most toxic compounds (WRI, 1992). Advanced sewage treatment plants that can further reduce specific pollutant levels cost twice as much to build and four times as much to operate as secondary treatment plants (EPA, 1989). This implies a possible cost reduction in water treatment if water hyacinth were used to clean polluted water before being discharged into the lake.

The community of Orange Grove (Mississippi) shelved plans for an expensive mechanical system and opted for a combination of wastewater treatment methods in which water hyacinth plays a leading role. In Florida, a 150,000 gallon-a-day water hyacinth based treatment plant (operated since 1978) whose costs were 40-70 percent below those of a conventional system has recurrent costs that are 25 percent less than those of conventional systems²⁵. In a similar vein, in Texas, installation costs of a similar facility came to only one twentieth of the quoted costs of a conventional system (NASA, 1996). In Lake Buena Vista, Florida, a prototype 100,000 gallon-a-day wastewater treatment plant was activated while in Georgia, a 350,000 gallon-a-day plant has been built. A more ambitious one is planned for San Diego—California that will be capable of providing for a population of over

²⁴ An associated study aims to answer some of the questions pertaining to the link between the hyacinth and fish catch.

²⁵ It is estimated that hyacinth based systems could halve the US\$330 million projected cost of upgrading the states sewage facilities by conventional means.

two million residents (NASA, 1996). Florida State is considering expanding water hyacinth technology on a statewide scale.

Relatively dry water hyacinth (18% water content) can be used as a soil amendment and as a source of plant nutrients. In Sarasota, Florida in 1972 a firm had great success with processing dried water hyacinth into a form which brought good results on tomato seedlings (Hussein, 1979) and can as well be used as mulch or compost (Gopal, 1987). Harvested plants can and are being used as fertiliser (FAO, 2000).

The plant can also be used as an energy source. Whole plants can be harvested and pressed to remove 75% of the water with modest energy input and can be used as animal feed (Hussein, 1979). Chopped water hyacinth plants put into fermentation chambers where they can be converted under anaerobic conditions with the help of methane bacteria, into biogas with a composition of 60-90% methane (CH₄) and 10-40% carbon dioxide (CO₂) can help alleviate the demand for energy in the region. The biogas generated by this process typically has a mean calorific (heating) value of 5,291 Kcal per cubic metre, which can be upgraded to about 7,963 Kcal by washing out the CO₂ content (Hassan 1979). In a limited way, it has been used to power stationary engines, tractors and cars, for lighting, cooking and heating, which therefore means that it could be tried around the lake to find out how these technologies could be tailored to fit the needs of the community living there. About 374 litres of biogas have been obtained from one kilogram of dried water hyacinth and consequently, one hectare of water hyacinth can under ideal conditions yield 900-1800kg of dry plant material per day and can give a daily calorific value equivalent to that produced by 233-465 litres of petrol (Hassan, 1979). It is reported that the plant juice has been used for the production of leaf protein concentrate and as substrate for yeast production (FAO, 2000).

These two opposing views underscore the duality of presence of water hyacinth: it presents (or has a potential of providing) advantages and disadvantages to different social and economic groups.

2.5 Household welfare and some of its determinants

To understand the determinants of poverty or welfare in all its dimensions, it helps to think in terms of peoples assets—human, natural, physical, financial and social—which they rely on to make living as comfortable as they can (Chambers, 1983; World bank, 2001). Fishing is an important economic activity for households in Lake Victoria while farming and livestock keeping also play a vital role in fulfilling people's cash and food security requirements (Geheb and Binns 1997). It has been hinted before that the health of the natural environment is a major contributory factor to the welfare of individuals.

Though not as important as improvements in women's education and status as well as food availability, environmental health for instance contributes around 12 percent of reductions in developing country child malnutrition

(Smith and Haddad, 2000). This observation is important noting that research also indicates Nyanza as one of the leading regions nationally as far as ill nutrition goes.

2.5.1 The role of women in the local economy

Among the food crops grown around the lake, are maize, beans, cotton, sugarcane simsim and groundnuts usually grown for subsistence purposes. It is also important to note that households living close to Lake Victoria have not only fishing as their income earner but agriculture too plays an important role in their livelihoods (Geheb and Binns, 1997). Women occupy an important place in food production and marketing both in fishing and agriculture. This makes women, an important gender to consider especially when looking at nutrition and health related issues. A study carried out in Southwestern Kenya has shown that food crops are in most cases women's responsibilities as opposed to cash crops which have been shown to be 'men's crops' from which 'men's income' is derived (Kennedy and Cogil, 1987; Kennedy, 1989). The study concludes that women tend to have different spending habits from men, allocating more expenditure to nutrition enhancing outlays such as food. Although not always, women tend to spend more on food both quantitatively and probably more importantly, qualitatively. In Rwanda for example, female headed households were found to spend more on food at a given level of income than male headed households (von Braun, de Haen and Blanken, 1991). Female headed households in Kenya follow an almost similar trend although they have slightly lower total consumption outlays than male headed households (Opondo, 1988). They were observed to allocate 66 percent of their expenditure on food while male headed households allocated 63 percent of their expenditure to food (*ibid*).

In South Nyanza, female participation in the labour force is higher than that of males (Republic of Kenya, 1994), and moreso in local marketing of fish (Geheb *et. al.*, 1997) indicating that the role of women in the local economy cannot be underestimated. Research in Kenya also shows that women in the rural areas work on average 58 hours a week but men only about 42 hours (Githinji, 1995). A related study concluded that where women controlled the crop and the income from the crop, they had the incentive to provide necessary labour that can result in considerable yield increases (Horenstein 1989). Women are usually though not always poorer than men for various reasons (Chambers, 1983). Female headed households mostly lack adult male labour and are also under-endowed in other aspects--notably--in land, capital, farm equipment and transport aids (Cleaver *et. al.* 1994; Gopal *et. al.* 2001).

Poor households in Africa and Asia have been observed to consume labour intensive goods than higher income households (Delgado *et. al.* 1998) and therefore, the tying up of women's labour in other activities can have catastrophic effects on household welfare. This is in addition to the negative impacts on health and education, which are prerequisites for a normal household (UNICEF, 1998). Women's triple responsibility--childbearing,

household management and production activities and the increasing pressures on their time and energy have important consequences for human resource development and environmental sustainability (Cleaver *et. al*, 1994). Women are responsible for the production of not only household goods and services such as meals and childcare, but even on the farm, which can mean strain on available time. These in addition to the role women play in the marketing (local) of fish (Geheb and Binns, 1997) raise important questions about the hyacinth with its impacts on the rural economy. This, other factors remaining constant, can undermine food security on the one hand and have many adverse multiplicative effects on a household's ability to raise farm labour and this in turn affects it's income-earning ability. These partly explain why the gender of a household head can make a difference in determining whether or not a given household is absolutely poor (Kimuyu, 2000).

2.5.2 Household income and diversity

Household income is arguably one of the most important determinants of household welfare. In general terms, in a monetized economy, money is the medium of exchange where the consumption unit (the household) exchanges money for consumption goods and services. Income has been shown to determine a wide range of household decisions e.g. decision to adopt new farm and forestry technologies, on the one hand, and the level of adoption of the technologies. Secondly, households respond differently to economic shocks given that some households possess a great deal of flexibility which is associated with the number of income sources available to them. They then are less vulnerable to such shocks (at least if these sources are not perfectly correlated) and thus under conditions of unfavourable economic changes impacting on a specific income source, there still remain a number of income sources from which to draw a livelihood (Glewwe and Hall, 1995).

The lakeside residents have little option but to stick to the fish extraction industry (Gréboval, 1982), even after being faced with some environmental shocks, it is then possible to hypothesise that their incomes are compromised via the environment-economy linkage shown on figure 2. Most part of the lakeshore is rural hence, provides little option for residents to switch between occupations²⁶. Further to this, agricultural land is at most not unavailable or unsuitable and given that the residents are culturally inclined to stay on to the fishing industry (Gréboval, 1989, Ikiara, 1999). For instance, 91 percent of fishermen go fishing since fishing is their only source of income and over 70 percent joined the fishing enterprise for similar reasons (Ikiara, 1999).

Poor households live in environments that are by definition unpredictable and for this reason, their incomes fluctuate every so often (Townsend, 1994). For example, subsistence farmers and others who cannot afford fertilisers depend on natural soil fertility, and subsistence fishers depend on the continued productivity of lakes, rivers, estuaries and coastal wetlands. When these systems are depleted, impoverished people cannot insulate themselves

²⁶ The investment options besides fishing and agriculture are in the *jua kali* industry whose growth is highly dependent on the performance of the local economy which provides the boost for other small scale industries.

from the effects as the wealthy can (WRI, 2000). They resort to adoptive strategies that lessen the impacts of environmental, economic or social changes on their resources, which include innovative landuse practices, the adoption of new technologies, economic diversification and changes in social organisation (Balterbury and Forsyth 1999). The use of wrong sized nets and the catching of fish using unorthodox means (e.g. poison) is probably such a strategy adopted by Lake Victoria fishermen to keep up with the runaway fishery. The hyacinth has been accused of carrying away fishing boats and nets, which are irrevocably the two most important capital investments in the rudimentary fishing activities in the lake. This may force fishermen to replace these items, using income which would otherwise have been used elsewhere such as in the provision of housing and education—which Kennedy 1989 refers to as 'men's roles' (Kennedy, 1989).

Although Alderman and Garcia, (1993) report that a short-term fluctuation in incomes should not necessarily translate into a similar fluctuation in consumption, long-term averages do determine how much is allocated to different expenditure areas. The fact that the hyacinth has been in the lake for about a decade means that any fluctuations in income resulting from its presence are clearly medium to long-term. One of the coping mechanisms that follow income fluctuations involves consumption smoothing and a lot of literature supports this thesis (Hossain, 1988; Ravallion, 1992; Townsend 1994; Zeller and Sharma, 1998). From research carried out in Pakistan, although seasonal trends in income appear, there is no such trend noticed in consumption implying that consumption smoothing is the norm (Alderman and Garcia, 1993). The coinsurance thesis argues that a community can provide individuals with insurance from individual or idiosyncratic risks. Within such a scheme, fluctuations in individual or household incomes may not easily be reflected in their consumption patterns. Townsend (1994) rejects the complete model of coinsurance since he found that most changes in household consumption are explained not by changes in their own income but by changes in average village consumption²⁷. However, the less than perfect correlation between average village consumption and household consumption changes suggests that household income still has a large influence on household consumption behaviour. Changes in average village consumption however can be used to trace changes in household consumption (Townsend, 1994).

2.5.3 Household capital

Closely related to household income is household capital. Capital is defined as that physical or non-physical entity which helps to augment production. 'Traditionally', capital has been categorised into two parts (i) physical capital (ii) human capital. Physical capital refers to the stock of both natural and manmade resources that are used to produce a flow of income into the household. Tools, plants, facilities, raw materials all fall into this category of capital. Human capital on the other hand refers to that inherent quality that

²⁷ For the coinsurance hypothesis to hold, two conditions are stipulated (i) fluctuations in individual incomes should not explain fluctuation in consumption (ii) household consumption should move with changes in average consumption of the village with an expected coefficient of 1.

improves upon the ability of certain individuals to perform tasks better than others and this tendency is due to an inbuilt ability that is activated through acquired knowledge and skills formed consciously through education and unconsciously through experience. It is conjectured that Schultz's education hypothesis holds and that education reduces the vulnerability of households to economic shocks and that educated people adapt better and faster to these shocks (Glewwe and Hall, 1995). Education here is used more loosely to encompass both formal and informal education or skill acquisition.

A third closely related but not so obvious (usually overlooked) dimension of household capital is that represented by its ability to mesh with other households such that each household in the mesh acts as a safety net for the others. It appears that the cointegration thesis mentioned above was after recognition of the role of social exchange in communities. Processes of social association can be conceptualised following Homans' lead "as an exchange of activity, tangible or intangible and more or less rewarding or costly, between two or more persons". The basic and crucial distinction between social exchange and economic exchange is that the former entails unspecified obligations to reciprocate and in this way, social exchange requires trusting others to discharge these unspecified obligations (Blau, 1964). Social capital is created when people learn to trust one another so that they are able to make credible commitments and rely on generalized forms of reciprocity rather than on narrow sequences of *quid pro quo* relationships (Ostom, 1994).

A study in Tanzania showed that social capital is an important determinant of household outcomes (Narayan and Pritchett, 1996; 1999; 2000). The most obvious benefit is that, many things which otherwise cannot be done individually are made possible by co-operation (Argyle, 1991). Immediate emotional rewards are also produced in the process. There also exists evidence to show that higher levels of social capital lead to higher incomes and not the other way round i.e. a cause-effect relationship has been identified moving from a high degree of social capital to higher income and not the other way (Narayan and Pritchett, 1996).

Ostom (1990) also suggests that the ability of communities to avoid excessive exploitation or undermaintenance of public assets that would result from purely individualistic behaviour under open access is attributable to social capital. Garret Hardin's thesis, 'Tragedy of the Commons' is based on 'purely individualistic behaviour and as individuals, the farmers are alienated, rational, utility maximizing automations and little else which Ostom continues to argue is only one of many outcomes'²⁸. Though generally true, Hardin's theory is largely a very simplified way at looking at the way people relate both with their surroundings and with the members of their community. The role of community co-operative action in solving problems with 'common property' elements can be a stable outcome and is potentially important (Narayan and Pritchett, 2000). Social capital potentially improves

²⁸ The sum total of their social life is the grim, Hobbesian struggle of each against all and all together against the pasture in which they are trapped.

the welfare of participants in the web by enabling the sharing of information, co-ordination of activities and helps in the making of collective decisions (Seralgedin and Grootaert, 2000).

2.6 Household Welfare and its measurement

Household welfare is in itself a multifaceted concept, which has presented many problems in its ideal measurement. Poverty is a concept closely related with welfare and since more amenable to measurement, has been used to make poverty comparisons. One important reason for making poverty measurements is for the making of comparisons, an assessment of which of two situations has more poverty. 'Poverty' can be said to exist within a given group of people when one or more persons do not attain a level of material well-being deemed to constitute a reasonable minimum by the standards of that society (Ravallion, 1992). Key questions in poverty assessments revolve around the aggregation problem²⁹ and the identification problem³⁰. Much literature has revolved around the aggregation problem.

2.6.1 Conceptual approaches to welfare measurement

2.6.1.1 Introduction

The theoretical basis of measuring welfare lies in the understanding that consumers consume what they consume the, reasons underlying this consumption being nothing else but utility or better still, satisfaction which they seek to maximize. Each individual's welfare depends not only on that individual's consumption of private goods but also on the consumption of non-market goods and service flows from the resource environment system (Freeman, 1993). These non-market goods and services in the case of Lake Victoria include *inter alia*, its aesthetic appeal and the role it plays in controlling river flow. These non-market goods and service flows are however difficult to price. Revealed preference analysis leads us to measure rather unobservable things such as welfare. Economists have gone round the problem by borrowing the construct of expenditure functions as substitutes for utility analysis (Baumol, 1977; Varian, 1990). The basic structure in conventional theory of the consumer consists of a simple constrained maximization model and utility is what there is to maximize (Baumol, 1977; Dwivedi, 1991, Hardwick, Khan, and Langmead, 1994). With transitive preferences, one can think of a situation where individuals in the society can choose between various bundles—within the confines of their incomes and prices—with the objective of maximally satisfying themselves. These households choose the most preferred bundle given prices and incomes, a choice that enables them, maximise their individual utility functions³¹. The conceptual clarity coming from a more theoretical approach through the use of social welfare functions enables us to measure, albeit indirectly, the effect of change or changes in the economic system.

²⁹ How to aggregate individual indicators of 'welfare' into a measure of poverty.

³⁰ How do we assess individual 'welfare' and at what level of welfare do we say that a person is not poor.

³¹ A utility function is assumed to exist and is an increasing function of consumption implying that the 'more is better' principle is operative.

2.6.1.2 A suitable indicator of living standards

The standard life cycle theory states that consumption tracks income over time and therefore becomes a good proxy for income (Branson, 1992; Schmidt-Hebbel and Servén, 1997). This is so if the savings ratio is a known constant, which could be time insensitive. Economic theory also maintains that the expenditure incurred by a household cannot exceed its income in the long term and therefore, household preferences are not revealed if this household cannot afford these goods and services (Baumol, 1977). Economic theory also assumes that household income usually is a major determinant of household welfare when the 'more is better' principle is in operation³². Yet, utility is unobservable and therefore unmeasurable, at least directly and for empirical purposes, one requires something, which is observable and is good indicator of household welfare or income. Income and consumption are used because they are either seen as ends in themselves or because they are considered to be sufficiently well correlated with other welfare indicators (Carvalho and White, 1997). Because there is no reliable measure of permanent income, let alone household welfare, household consumption expenditure, which is regarded as a more suitable measure of households' economic welfare than current income, is normally advocated for (Kakwani and Subbarao, 1993). In this work, food is assumed to be the foremost basic need and therefore the defining ingredient in poverty. However, empirical observation suggests a common set of capabilities that are considered basic in most societies. They include the capabilities of being adequately nourished, avoiding preventable morbidity and premature mortality, being adequately sheltered, having basic education, being able to ensure security of the person, having equitable access to justice, being able to appear in public without shame, being able to earn a livelihood, and taking part in the life of a community (UNOHCHR, 2002). The relegation of other needs in this work is prompted by the need to remain simple and focussed and this should in no way suggest that other needs are not important.

There are two standard rationale for using expenditure as an income proxy, one empirical and one theoretical. Empirically, it is difficult to measure incomes especially rural incomes, which are subject to large seasonal swings, which may derive from a myriad of activities with associated costs that may be difficult to assign (Ainsworth and van der Gaag, 1988; Hentschel and Lanjouw, 1996). Consumption expenditures are often easier to estimate since households probably purchase and consume a narrow range of goods and services (Hentschel and Lanjouw, 1996) and are likely to understate their incomes than overstate their expenditures (Johnson, McKay and Round, 1997). On theoretical grounds, with properly functioning capital markets, expenditures are a better measure of permanent income than is current income (Ainsworth and van der Gaag, 1988; Benjamin and Deaton, 1993; Narayan and Pritchett 1996, Deaton, 1997). Household consumption expenditure per capita therefore becomes a major indicator of a household's level of well-being and many studies have used this measure.

³² Given prices and quantities, more can be purchased if more income is available since individuals cannot consume more than what their respective incomes can allow.

There are two distinct approaches in the measurement of 'well-being' or 'welfare' which differ in terms of the importance one attaches to the individual's own judgements about his or her own well being (Ravallion, 1992). The concept of 'standard of living' can either be 'welfarist' or 'non welfarist' and is generally taken to depend on an individual's consumption of privately supplied goods and services. Following such an approach, current consumption is taken to be the preferred indicator of well-being in applied work and income is only used as a proxy for consumption. The 'standard of living' is not the only way to measure welfare. A consumption unit's opportunity for consumption would be what we really want to measure rather than what the consumption unit individual actually consumes. Household expenditure then becomes a good indicator of a household's opportunity for consumption since it provides information not just on what a household is able to command based on its current income, but also, whether it is able to access credit or household savings when current incomes are negative (Hentschel and Lanjouw, 1996). Consumption expenditure has thus been more popular in development literature and dictates a preference for consumption as the welfare indicator reflecting the importance attached to specific forms of commodity deprivation especially food.

Food expenditure enters the utility function in two ways (i) directly as a consumer good and (ii) indirectly as an input into the production of health while other inputs such as healthcare enter into health production as inputs but do not directly contribute to household utility (Alderman, 1990). From an economic viewpoint, good health facilitates development by raising people's productivity, permitting the use of natural resources previously inaccessible on account of disease and freeing resources that would otherwise have been used to restore peoples health (Nganda, 1996). Many poor rural households tend to spend larger shares of their income on food, the 'first necessity' and in the eyes of many people, including development economists, low welfare levels are closely related to whether or not people have enough to eat (Deaton, 1997)³³. From a human rights perspective, poverty consists in the non-fulfilment of a person's human rights to a range of basic capabilities – to do and be the things he or she has reasons to value. Capability failure is thus the defining attribute of poverty (UNOHCHR, 2002).

2.6.1.3 The unit of analysis: The household

A household from which information is sought is defined in many surveys as a group of people who live and eat together. It is usually taken to mean a housekeeping or consumption unit. It is an important unit for investigation because it supplies labour, is directly responsible for significant part of economic activity, and its well being reflects the outcome of development effort as well as economic and social problems. It has become customary for Economists to interpret household behaviour by assuming that its choices

³³ An attractive definition of poverty is that, a person is poor when he or she does not have enough to eat, or in explicitly economic terms, when they do not have enough money to buy the food required for basic subsistence.

reflect a unitary view among its members of what constitutes their well being and the model implicit here is one of a utility maximising household (Dasgupta, 1995). The UN guidelines suggest that the 'common pot' dominates the 'common roof' for household membership purposes³⁴ (Johnson, McKay and Round, 1997). The decision making role is most important from the conceptual standpoint. This definition recognises the households' function as a consuming unit and to a lesser extent, an asset owning unit (*ibid.*). the head of the household is the spokesperson for the members who constitute that particular household and all views held by the household head are assumed to be the views of all household members.

2.6.2 Engel's Law

Ernst Engel came up with the thesis that as income increases, the proportion of it spent on food decreases, *Ceteris paribus* and this is the familiar Engel's Law. The hypothesis that the living standard can be measured by the food share is based on the analysis of Belgian budgets of working class families collected in 1853 where he found that needs are hierarchically organised with food as the basic need. Based on a conception of the living standard as the level of needs which a family is able to satisfy, and his findings that the budget share of the primary need decreased with total expenditure, he concluded that the food share summarises in a single quantity the degree to which an individual or a family can satisfy its needs (Folkertsma, 1996). The food share is singled out as a rough measure (or indicator) of household welfare hence, households with a large food share are almost always poor (Hentschel and Lanjouw, 1996). In more technical terms, the law states that the share of food in total expenditure is a decreasing function of the level of prosperity of the household and the law appears to hold almost universally (Madalla and Miller, 1989; Mukras, 1993, Deaton 1997). A generalisation of Engel's law states that with increasing prosperity, the budget share of any good initially increases with income and its budget share corresponds with its 'luxury' status. As income increases, a 'necessity' has a decreasing budget share and its budget or income elasticity is less than one³⁵ (Lipse and Chrystal, 1995). As opposed to absolute household per capita expenditure, the food share may be more encompassing especially when different food items make up the consumption basket of different households.

There is evidence to show that the income elasticity of food like the budget share is inversely related to income, with an elasticity, which may be as high as 0.8 or 0.9 at very low income levels and close to zero for high incomes (Houthakker, 1987). This in other words means that poor households generally spend a greater proportion of their income on basic needs—food and shelter—and therefore have less to spend on healthcare, education, and the transport that is often essential to reach jobs that pay a living wage (UNEP, 1999). Such conditions can limit earning ability and opportunities to

³⁴ For instance, a boarder who does not lodge is included as a household member but a lodger who does not board is excluded from household membership.

³⁵ A commodity may go through a prosperity cycle being a luxury and a normal commodity for the poor, a necessity and a normal commodity for the better off and perhaps a necessity and inferior commodity for the rich.

escape poverty, resulting in a vicious circle of poor education, poor health and low income.

Differences in expenditure patterns across households are the norm and can be attributed to three factors (a) the variation in available means (b) variation in relative prices (c) differences in other household characteristics (Barten, 1987). The standard convention of household budget analysis that prices are the same for all households is an assumption that has traditionally separated household budget analysis from demand analysis. Household budget analysis investigates the nature of Engel curves while the latter concerns itself primarily with the measurement of price effects (Barten, 1987).

2.6.3 Empirical approaches to welfare measurement

The most important source of data for making welfare assessments is a household survey. In these surveys, income and consumption are used because they are either seen as 'ends' in themselves or because they are considered to be sufficiently well correlated with other welfare indicators (e.g. literacy, nutritional status) to suffice by themselves as measures of poverty or welfare. For empirical research, the issue of the measurement of 'available means' or 'level of prosperity' arises. The most common indicators used in practical work are based on household income, and household consumption expenditure, the latter being preferred for two important reasons as outlined above in section 2.6.1.2. Once more importance has been given to an ordinal measurement of welfare (the cornerstone of neoclassical consumer theory) rather than cardinal measurement, consumption has been found to be a good indicator of welfare (Hentschel and Lanjouw, 1996).

Consumption is preferred over income under a quantitative approach since on the one hand, incomes are notoriously difficult to measure and the former variable is more accurately recorded for households that have diverse sources of income (Ainsworth and van der Gaag, 1988; Glewwe, 1990; Bouis and Haddad, 1990; Benjamin and Deaton, 1993; Narayan and Pritchett 1996; Hentschel and Lanjouw, 1996; Deaton, 1997). Besides, households are more likely to underreport incomes than expenditures (Alderman and Garcia, 1993; Johnson, McKay and Round, 1997). Secondly, consumption is less likely to fluctuate as much as income and this serves as a more reliable indicator of a household's long-term level of well being (Ahmed and Hossain, 1990). The composition of household consumption offers further insight into the living conditions of a household, the focus often being food and non-food budget shares. Consumption includes household expenditure in kind, income consumed by the household, consumption of home production and consumption of services from durable goods. Total wealth of a household defined as the market value of its real and financial assets plus the present value of expected future income from other sources, might be the most appropriate concept. However, it escapes direct measurement, because it is based on subjective expectations while also the ownership of assets is not well observed. The same applies to the concept of permanent income which

is the amount of money which may be consumed leaving total wealth unchanged (Houthakker 1987). Current income is apt to include transitory components and is presumably anyway not faithfully recorded (Hentschel and Lanjouw, 1996; Kakwani and Subbarao, 1993). The amount of total expenditure is usually readily available and might be closely related to total wealth or permanent income and this makes it an attractive proxy for available means or prosperity when explaining expenditure patterns. This means that income or its proxy—expenditure are important although not the only variables that explain the behaviour of the Engel curve.

Individual as opposed to household surveys on the one hand would be very expensive to conduct and on the other hand, would still be prone to many biases³⁶. A single cross section based on one or two interviews is the most common (Deaton, 1997). Panel data—a number of observations made over a certain period—are inherently more expensive and deny one the opportunity to cover wide areas. They are also subject to panel ageing where the initial sample becomes increasingly unrepresentative over time. Examples of the former type of survey include some of the World Bank LSMS's³⁷ surveys and the Welfare Monitoring Surveys (I, II, & III) carried out by the Central Bureau of Statistics. Examples of panel data include the IFPRI survey of rural households in Philippines (Bouis and Haddad 1990), the CILSS, and in Kenya, IFPRIs 1984-1987 study on the effects of sugarcane production on food security, health, and nutrition (Kennedy and Cogill, 1987; Kennedy, 1989).

Households differ in size and composition, and so a simple comparison of aggregate household consumption could be quite misleading about the welfare of individual members of a given household (Folkertsma, 1996; Carvalho and White, 1997). Intuitively, a large household and a small household are equally well off **if and only if** they devote the same fraction of their budget to food expenditure (Deaton, 1997). The analysis of household budgets should take into account this fact since Engel had also discovered that the share of food in a household's budget is greater for large households than for smaller ones (Deaton and Muellbauer, 1980). He had also realised that expenditure data for different household types can neither be compared directly nor on a per capita basis due to the differing needs of household members. Therefore, measures should be stated in terms of adult equivalent, measuring the number of adult men that the household is equivalent to (Ravallion, 1992). Since most income-expenditure data comes from the household level, but what we are interested in is the welfare of individuals, it becomes necessary to transform household level data into data relating to an individual. The most widespread 'rule' in moving from household data applied in practice is that all household members receive the same fraction of household expenditure. One drawback in proceeding this way is that, all family members do in fact require different shares of the household's total resources in order to reach the same level of welfare (Hentschel and Lanjouw, 1996; Deaton, 1997). In household budget analysis, the use of

³⁶ Household surveys are by no means free from some biases either.

³⁷ By 1995, surveys with several if not all of the hallmarks of LSMS had been conducted in at least eighteen countries among them, Cote d'Ivoire, Ghana, Mauritania, Jamaica, Bolivia, Morocco, Venezuela, Russia, Guyana, Nicaragua, South Africa, Vietnam, Tanzania, Ecuador and Romania (Grosh and Glewwe, 1995).

household demographic structure can be used to construct “adult equivalence scales”, numbers that show how much a child costs relative to an adult and these scales can be used to correct household expenditure for differences in household composition.

To make expenditure comparisons, Engel suggested measuring household size in units he called *quets*³⁸. As a unit, he proposed a new-born baby to represent the unit ‘*quet*’ and as one becomes older, he represents more ‘*quets*’ reflecting roughly the growth of the individual. The household size therefore becomes the sum of ‘*quets*’ of its constituent members (Folkertsma, 1996). The problem with this approach however is that, growth is not strictly constant with time. Since Engel, there have been numerous attempts to come up with equivalence scales—numbers that make the comparison of different households meaningful. For instance, Rowntree (1901) tried specifying basic needs based on dietary studies by Atwater (1899) while Sydenstricker and King (1921) suggested determining living standards not on the basis of what households should spend to satisfy their needs according to expert opinion but based on what they actually spend (Folkertsma, 1996). In Kenya, many household level surveys have been conducted. Adult equivalent scales were developed for the country by Anzagi and Bernard (1977) and the first poverty report in Kenya employs the adult equivalent concept and scales developed for Kenya in the 1977 study. This study adopted a weighting of 0.24 (for anyone aged 0-4 years), 0.65 (for those between 5-14 years) and a weight of 1 for all persons above 15 years of age. The same scale was used in a 1986 ILO study of food poverty in Kenya (Greer and Thorbecke, 1986). Differences in needs by sex are assumed not to exist according to these scales.

Another question lies with the functional form of the Engel relationships. Houthakker (1957) found that Engel’s law is confirmed by more than 40 surveys from 32 countries. He contented that if one adopts Engel’s conception of the standard of living and if his empirical law that the food share decreases with increasing income is not refuted, his method seems plausible. The systematic study of the mathematical form of the Engel curve began with linear specifications but when shown to be unrealistic, a variety of other functional forms have been developed and explored. Income is the most prominent in cross sectional analysis but does not explain all the variation in household expenditure. Houthakker’s international comparison of Engel behaviour led to his conjecture that in the absence of reliable expenditure data for a nation, “one would not be very far astray by putting the partial elasticity with respect to total expenditure at 0.6 for food, 1.2 for clothing, 0.8 for housing and 1.6 for all other items combined”. ‘Engel’ relationships computed for six African countries confirmed the conjecture by Houthakker, Ferber and others³⁹ (Okunde, 1985). Using a linear expenditure system expenditure elasticities in Kenya were estimated as 0.796, 1.695,

³⁸ The Belgian mathematician and statistician (Adolphe J. Quételet) had discovered a regularity between the length and weight of persons and Engel based his unit on Quételet’s work.

³⁹ The countries investigated included Ghana, Kenya, Malawi, Sudan, Tanzania and Uganda.

1.506, 0.836 and 1.72 for food, clothing, manufactures, fuel and other commodities respectively (Greer and Thorbecke, 1986). Non linear Engel relationships were popularised because they have consistently proven to yield better estimates of the curvilinear relationships which actually characterise most Engel relationships (Mukras, 1993), Deaton, 1982). Houthakker's (1957) international comparison employed a non linear specification and on the basis of Houthakker and Prais, the Engel curve for a commodity is of 'quite unspecified shape' and therefore statistical evidence should be relied upon for the choice of the equation that best estimates the true relationship (Mukras, 1993). Engel curves estimated for Zambia show that marginal changes in the share of food in the budget did not vary across income quintiles (Celis and Bliven 1991).

In poverty calculations, it is assumed that there exists a group of food items referred to as a 'food basket' that are consumed commonly. The food basket is used to derive a food poverty line—the minimum food expenditure determined on the basis of a recommended minimum nutritional requirement (calories) for maintenance of the human body and healthy growth⁴⁰. For example, the food basket employed by the WMS II included bread, cereals, fish, eggs, fruits, beans, sugar, maize, meat, milk, oils and fats, vegetables, roots, tea and coffee (Republic of Kenya 1999). Households were found to spend a larger proportion of their income on food accounting for 59 percent while medical and educational expenditures accounted for 5 and 3 percent of the total outlay respectively (Republic of Kenya 1996). The non-poor were found to spend more than twice the amount of the poor enabling them to achieve not only adequate food quantities, but also a more varied diet (Republic of Kenya, 1999b). From the third WMS, food was found to take up over 70% of household budgets and the non-poor were found to spend twice the amount of the poor enabling them to achieve not only adequate quantities but also a more varied diet (Republic of Kenya, 1999). From an earlier study in 1981/82, food was found to constitute between 60% and 73% of the household budget (Opondo, 1988). The three Welfare-Monitoring Surveys carried out by the CBS consistently reveal that the share of food in total household outlay is indeed a good indicator of living standards and usually, food takes up over half of household budgets.

⁴⁰ The standard is the FAO/WHO minimum recommended daily energy allowance (RDA) of 2,250 calories per adult male per day.

CHAPTER THREE

3.0 Methodology

This chapter tries to develop a scheme with which the welfare of households can be measured empirically. This chapter collates all bits of information from previous chapters and puts them in the perspective of Engel curve analysis, which is the backbone of this study. In this chapter, the specification of the Engel curve used in the study is presented as well as the data requirements for the analysis. It describes the process undertaken to gather data, which is used to answer the questions posed in chapter one. The ideas presented here are thus not discussed in detail since they have been discussed or implied from the previous chapter.

3.1 Conceptual and theoretical framework

According to Engel's law, the share of food in total expenditure is inversely related to the household's expenditure implying that the expenditure elasticity of food is less than 1. Of all empirical regularities observed in economic data, Engel's law is probably the best established (Houthakker, 1987) and holds not only in cross sectional data but has also been confirmed in time series analysis (Deaton, 1997). Engel's law states that the lower a family's income, the greater is the proportion of it spent on food (Koutsoyannis 1979; Maddala and Miller, 1989; Pearce 1995). This law helps link expenditure on individual goods to total expenditure and at this point, we assume that money itself can be thought of as a good and thus one unit of this money has the price of one unit (Perman, Ma, McGilvary and Common, 1999). The truth of Engel's law implies that among households with the same demographic composition, those with larger food shares in the total household budget are generally those with lower levels of income, *Ceteris paribus* with lower levels of welfare (Deaton and Muellbauer, 1980; Houthakker, 1987; Deaton, 1997). The analysis is done to estimate a consumption response to income changes for aggregated commodity groups and in this study, all food items are collapsed into one group. To operationalize this analysis, a variant of the Working-Lesser model is used to estimate the income consumption relationship for individual commodities and to estimate how these relationships change as household income changes.

The principal purpose of this study is to estimate the income-consumption relationship and establish how this relationship changes in the presence of water hyacinth and as other socio-economic characteristics change. For this purpose therefore, the complications of household expenditure responses to price shifts need not enter the analysis since the study is distinct from demand analysis. As suggested before, household expenditure takes the place of household income for all practical purposes. The linear Engel curve of the form;

$$E_i = \alpha_i + \beta_i E + \varepsilon_i \dots\dots\dots(i)$$

where E_i is household expenditure on food, E is total consumption expenditure and α is a constant; does not permit the marginal budget share β to vary at all if we assume that all households differ only in their total consumption expenditure (Hazell and Röell, 1983). More curvature is clearly required to make an improvement on (i) and to do this, a 'restricted'

nonlinear specification of the Engel function is adopted. This is restricted in the sense that not all relevant RHS variables are present. Working's proposition that the food share is linearly related to the logarithm of total expenditure is a good point to start.

The form;

$$E_i = \alpha_i + \beta_i E + \gamma_i E \log E + \varepsilon_i \quad \dots\dots\dots(ii)$$

is a modification of the Working-Leser model and differs from the original in that it includes an intercept (Hazell and Röel, 1983). In theory, E_i is zero when E is zero, a restriction that ought to be built into the model. Zero observations on E however lie well outside the sample range. Before proceeding further, a number of restrictions need to be noted. Thus;

$$E = \sum E_1 + E_2 + \dots\dots + E_i + E_j \quad \dots\dots\dots(iii)$$

$$E_i = \sum e_1 + e_2 + \dots\dots + e_n \quad \dots\dots\dots(iv)$$

$$E_i > 0 \quad \dots\dots\dots(v)$$

$$E > 0 \quad \dots\dots\dots(vi)$$

there are j expenditure categories of which food is among these categories and there are n different food items. Relationship (v) is as it is because one MUST ingest food in order to stay alive and since E_i evaluates to a non zero positive integer, it follows that (vi) is automatically satisfied. Observing the restriction that $E_i=0$ when $E=0$ in the Working-Leser Engel curve may lead to poor fits and unwarranted changes in the sign of the second derivative of the estimated curve (Hazell and Röell, 1983). It is likely that the zero intercept specification is only relevant if higher order non linear terms are included in the model (*ibid*).

In order to provide answers to the questions posed in chapter one, the Engel function to be estimated is derived by dividing (ii) by E , which therefore evaluates to the form (vii) where (w_i); the food share becomes the dependent variable. The Engel curve to be estimated is therefore of the form;

$$w_i = \beta_i + \alpha_i \frac{1}{E} + \gamma_i \log E + \tau_{ik} Z_{ik} + \varepsilon_i \quad \dots\dots\dots(vii)$$

where w_i is the food share i.e. E_i/E and E is as before, total household expenditure. Matrix z is a vector of other socio-economic variables thought to affect the Engel curve and contains;

- Z_1 Household size (in adult equivalents)
- Z_2 Dummy for presence of water hyacinth (1 if hyacinth is present, 0 if otherwise)
- Z_3 Household social capital (No of transactions between household and other households)
- Z_4 Households physical capital (Present value of physical assets owned by household—ksh)
- Z_5 Human capital (experience of household head in present occupation-- years)
- Z_6 Dummy for human capital (education) (1 if household head attended secondary school, 0 if otherwise)
- Z_7 Age of household head (years)

- Z₈ Dummy for gender of household head (1 if male, 0 if otherwise)
 Z₉ Dummy for main occupation of household head (1 if fishing, 0 if otherwise)
 Z₁₀ Dependency (number of income earners as a proportion of household size)
 Z₁₁ Dummy for district of residence (Busia =1; 0 otherwise)
 Z₁₂ Dummy for district of residence (Nyando =1; 0 otherwise)
 Z₁₃ Dummy for district of residence (Migori =1; 0 otherwise)
 Z₁₄ Subsistence orientation (% of food acquired in cash)
 Z₁₅ Infrastructure (Distance from homestead to nearest motorable road--metres)
 Z₁₆ Dummy for poor household in hyacinth infested area? (yes=1, no=0)
 ε_{ij} Stochastic disturbance

The Engel function above has been used in various studies (see for example Hazel and Röell, 1983; Ahmed and Hossain, 1990; Wanmali, 1992; Delgado *et.al.* 1998). When the Engel curve is estimated in share form, potential heteroscedasticity problems are mitigated (Hazel and Röell, 1983, Delgado *et.al.*, 1998).

Further subtle refinements to the Engel curve are made. For example, when looking at an aggregate such as total household expenditure as postulated by Working, results can mislead one into assuming that welfare is high even though for example in an extreme case, all the expenditure in the household goes to one person. This would therefore lead to an erroneous conclusion about welfare of the household in general (Deaton, 1997). The adult equivalent scales used in the WMSIII are therefore incorporated in this study as weights to deflate total household expenditure into expenditures per adult equivalent.

Chief among variables that have been used to explain the variation in Engel relationships are family size and composition since a household consumption measure of welfare that does not take into account differences in household composition can give a biased estimate of welfare (Deaton and Muellbauer, 1980, Deaton, 1997). In addition to household composition are variables that represent location, asset ownership, education and also composition of domestically produced food. The latter has for instance been found to be a significant determinant of household expenditure patterns in Nigeria (Makinde *et.al.*, 2001).

In the Engel curve specification above (expression vii), the water hyacinth variable enters the function as a slope as well as an intercept. When the Engel curve is estimated in share form by ordinary least squares (OLS), the adding up condition is automatically satisfied (Delgado, *et. al* 1998)⁴¹. This specification as opposed to the original linear specification of the Engel curve is an improvement on Working's specification and has the advantage of being consistent with a utility function. It allows for non-linear relationships between consumption and income. The transformation of expenditures to

⁴¹ Adding up ensures that $\sum \beta_j = 1$; $\sum \alpha_j = \sum \gamma_j = \sum \tau_j = 0$

budget shares and of total outlay to its logarithm induces an approximate normality in the joint density of the transformed variables, so that the regression function is approximately linear (Houthakker, 1987; Deaton, 1997). To introduce more curvature to the Engel function, a specification with a second order polynomial in income has been tried by Deaton (1982) and this still allows the Engel curve be consistent with utility maximization (Singh, Squire and Strauss, 1986). However, one drawback which afflicts the specification above is that with shares, the regression yields a very low coefficient of determination (Hazel and Röell, 1983).

3.2 Research design

A quasi-experimental research design is implied all through since the subject of study could not be studied under a controlled experiment just as it applies to many social science inquiries. A household budget analysis was envisioned for the study and thus a household survey that covered a sample of households living at the Kenyan side of Lake Victoria was executed. To gather useful data necessary to answer the questions posed, primary and secondary sources of data were relied upon. A structured household questionnaire was designed taking into account the data needs of this study. The household questionnaire was adopted from the Living Standards Measurement Surveys (LSMS), which are designed to collect household data from which the analysis can be done on many aspects of welfare and their interaction, rather than on precise measurements of a few aspects of welfare. This is because the LSMS trades topic specific detail for comprehensiveness, and it is anticipated that data so produced yields information that in total is much more important than the sum of its components.

Experience with LSMS-type data indicates that this goal has been reached (Ainsworth and van de Gaag, 1988). A partial listing of studies using the LSMS survey format in 1995 was put at 320 since their inception in the 1980's (Grosh and Glewwe 1995). Primary data collected through interviews by use of the questionnaire included data on household income, consumption, remittances, household physical capital, savings, credit, employment, health, schooling, nutrition and housing. Secondary data sources included published and unpublished manuscripts from the Margaret Thatcher Library, Chepkoilel campus, KARI headquarters library, The Central Bureau of Statistics as well as numerous other libraries.

3.2.1 The survey instrument

The data required to fit in the Engel curve was gathered through the LSMS type household questionnaire mentioned above. The questionnaire was divided into sections, with each section collecting specific information about the household (see appendix I for more details). The sections included first round questions **[R1]** and second round questions **[R2]** arranged in the order shown below

- a) Household Roster: designed to identify a household and its constituent members, their gender and age. **[R1]**
- b) Economic activities: questions designed to identify occupation of household members. **[R1]**

- c) Annual household expenditure: questions designed to elicit responses on itemised expenditures for the entire household over the last 12 months (1 year) preceding the date of interview. **[R1]**
- d) Annual household income: Responses sought to measure each households annual income accruing from all sources over the entire 12 months preceding the interview. (Notice that this particular section comes after the expenditure section since it was assumed that if these sections were interchanged, households may have an incentive to intentionally bias their incomes to be in line with their expenditures). **[R1]**
- e) Remittances: This section helped account for 'income flows' in and out of the households during the entire 12 month period preceding the interview. **[R1]**
- f) Physical capital: This section dealt with the estimation of the net worth of all household physical assets. **[R1]**
- g) Household food expenditure: This section being the first after a one week interval following the round one questions estimated the households expenditure on different food items over the past one week as well as an attempt to measure the expenditure on the same food items over a 12 month period. **[R2]**
- h) Water hyacinth impacts: This was in effect an attempt at valuing the impact of water hyacinth control using two control methods (biological and physical). **[R2]**
- i) Anthropometrics: This section was an attempt to estimate nutritional impacts of the presence of water hyacinth on household members. **[R2]**
- j) Envisaged income: This section tried to estimate the discrepancy between actual household income and the poverty line. **[R2]**
- k) Savings and credit: This section was an attempt to estimate a household's credit standing (savings and credit portfolio) or credit worthiness. **[R2]**

3.2.2 Sample selection

A Multistage stratified sampling protocol was employed in selecting households from the Kenyan shores of Lake Victoria that participated in this study in total. A conservative formula given by $N=1/\text{error}^2$ was used to determine an appropriate sample size. These households were drawn from four districts namely; Busia, Nyando, Rachuonyo and Migori, which formed the first strata hence, administrative boundaries served as strata boundaries. To select these households, a list of sub locations from the selected four districts adjacent to Lake Victoria was prepared indicating the shoreline status *vis-à-vis* the hyacinth. Five sub locations were randomly selected from this list and these included Mavinju and Sisenye in Busia, K'Okoth 'B' in Rachuonyo, West Kabodho in Nyando and Magungu in Migori district. Magungu, K'Okoth 'B' and Sisenye sub locations were indicated to be free from the water hyacinth while the rest were hyacinth infested areas. A listing of households from all of these sub locations was sought from the respective area Assistant Chiefs. This list served as the sampling frame and in total, 3,766 households were listed distributed in the five sub locations. From this

list, 350 households were selected randomly to participate in the survey and households from West Kabodho and Mavinju sub locations composed 23.7 and 17.1 percent of the sample respectively, a combined 40.8 percent of the entire sample. Households from Magungu, Sisenye and K'Okoth 'B' sub locations made up 22, 18.3 and 18.9 percent of the sample respectively (see table 3.1). The selected sample comprised of two groups of households one residing close to the lake where the water hyacinth had been resident while the remaining group was comprised of households living close to the lake but where the water hyacinth had not been resident. In this form, was expected that the latter group would form a control group with which to compare results.

The multistage sampling procedure was chosen since costs per observation would be lowered unlike the case if a simple random sample had been drawn from households in the study area. Secondly, stratification produces a smaller bound on the error of estimate than that produced by a simple random sample of similar size especially if measurements within each strata are homogeneous (Scheaffer, Mendenhall and Ott, 1990). There was a difficulty in achieving a judgement free description of what water hyacinth infestation should be—are spatial distributions more important than temporal orientations—with respect to water hyacinth infestation. Since there was no data relating to the status of infestation along the lake (in terms of both intensity and duration of infestation), expert opinion from key informants was relied on in the selection of the study area. The sample also tried to control for regional differences; agroecological zone, differences in the distance from the water hyacinth⁴², as well as other peculiarities that may be found among the population.

Table 3: 1 Details regarding the sample households

Sub location	Kokoth 'B'	Mabinju	Sisenye	W. Kabodho	Magungu
District	Rachuonyo	Busia	Busia	Nyando	Migori
Location	K'Okoth Kataa	Khajula	Bunyala North	Nyalunya	North Kadem
Area (km²)	13.3	7	9.2	21.7	28.4
No of households in 1999^a	657	610	725	930	844
Households per sq km	49.4	87.1	78.8	42.9	29.7

⁴² There was no specific reason why it was expected that distance from the lake could influence a households vulnerability to water hyacinth infestation. However, it was thought that living next to the lake makes a household more vulnerable to diseases transmitted by mosquitoes that breed among the water hyacinth plants, vulnerability which decreased with distance from the lake.

No of persons in 1999^b	3,217	2,504	3,673	4,049	3,917
Persons per sq km	242	358	399	187	158
No of sampled households	66	60	64	83	77
Sampled households as percent of total	18.9	17.1	18.3	23.7	22
No of villages in sampled	21	15	13	11	6

Source: ^{a,b} 1999 National Population and Housing census.

3.2.3 Preliminary activities

Eight enumerators were selected from residents of the sub locations from which the sample households belonged. In selecting the enumerators, the local administration was approached to provide names of probable candidates for the exercise. Some of the conditions placed upon the selection were that they had to have been involved in similar exercises as well as being unengaged in other activities, which would prevent them from giving enough attention to the survey exercise. These were in addition to having completed at least their O-level examinations in addition to having a good command of English, Kiswahili as well as basic algebra. The eight enumerators selected for the exercise had all been involved during the 1999 national population and housing census carried out by the Central Bureau of Statistics in their respective areas of residence. It was anticipated that this would be a cheaper option than sending a team of non-resident interviewers into the study areas, which would have turned out to be a more expensive option. This choice was also necessitated by the nature of the study where it was felt that respondents would be more 'open' or 'at ease' when answering questions posed to them by people that they knew as opposed to total strangers. It was felt that the interviewers (residents) were in a better position to build considerable rapport with respondents and hence the choice of locals as interviewers. Besides, the instrument to be used was worded in English and it was foreseen that for those respondents who did not understand English, some translation of questions from English to the local language was an inevitable option. When translating questions into the local language, it was therefore more appropriate to have interviewers who fully understand the local language and automatically, residents were the best available option. All enumerators were tested for their competence in basic algebra as well as their command of the English language. Results indicated that each of these enumerators had a good grasp of these, which were central to the minimisation errors originating from interviewees. Besides the questionnaire, each enumerator was provided with survey materials *viz.*, calculator, blue ballpoint pens, pencils, notebook, eraser, an interviewers manual which included a code book (see appendix) and folder in which to carry questionnaires. A tentative timetable and interviewer list to enable efficient scheduling of interviews were provided to each interviewer. In addition, electronic bathroom scales were given to the interviewers to help them

record weights of interviewed household members. The interviewers' manual drafted following the household questionnaire provided the definitions of all terms used in the questionnaire as well as the meanings of the questions posed in the questionnaire as well as accompanying instructions on how to conduct oneself during the interviews.

The enumerators were briefed on the requirements of the questionnaire and stress was placed on the importance of understanding the questionnaire even before the real work of data collection began. Before actual fieldwork could commence, each enumerator was taken through each of the steps in filling the questionnaire by the assigned supervisor. During the month of December 2000, enumerators were asked to attempt mock interviews at home after which questionnaires were checked for indications of exigencies. Since this 'training' was also intended to be part of the questionnaire pre-testing stage, complaints about the questionnaire were recorded. One of the major points of concern raised by the interviewers was the length of the questionnaire since it was not possible to complete the questionnaire within a reasonably short time. After pre-testing the questionnaire, it was realised that it took long to fill in the questionnaire and hence, respondent fatigue. The questionnaire was therefore trimmed and redrafted by removing all unnecessary detail. Therefore, some of the sections of the questionnaire were dropped and others combined so as to shorten the time between start and end of interviews. A consequence of this was a loss of detail especially in reporting incomes but since expenditures are a better estimate of permanent income, it was felt that this would not render a big blow to the results of the present work. A further pre-test was done with the revised instrument, which is presented on appendix I.

3.2.4 Data collection

Between the months of January and March 2001, the household questionnaire was administered in two rounds **one week apart**. The reason for doing this survey in two rounds was that a common basis for measuring household consumption needed to be adopted so as to make it possible to make interhousehold comparisons for a comparable time period. It has been found out that long recall periods ultimately lead to a situation where respondents give responses that are not factual but normative. For instance, the questionnaire was designed to ask questions that elicited factual answers (ostensibly factual questions used) and explicitly normative questions were avoided. If the recall period were lengthened, there was a possibility of respondents giving erroneous information due to memory lapse⁴³ (Scott and Amenuvegbe, 1990).

During the first round, information on general characteristics of the household was sought as well as education and health expenditures, housing, occupation of members, annual household expenditure, annual household income, income transfers or remittances and physical capital available to the household. The second round aimed at obtaining a complete profile of the

⁴³ For instance, in Ghana, it was estimated that each day added to the recall period makes reported expenditure on frequently purchased items to drop by 3 percentage points.

household's food consumption, their conception of water hyacinth and its control, their conception of 'adequate' income, anthropometrics, as well as net debt. This information served as a basis upon which, the description of income distribution, its composition as well as the structure of household consumption can be done. The two round approach provided a convenient reference period for reporting household expenditures and also an opportunity to submit round one data to consistency checks, such that, any inconsistencies detected during the first round were corrected during the second round. Visits to each of the sub locations were scheduled each week so that further checks on data collected from the field could be done before these data could be retrieved and entered into the computer.

CHAPTER FOUR

4.0 Data Processing and Analysis, Results and Discussion

This chapter describes the data processing and analysis and goes further to present results of the analysis. It also links these results to the major hypotheses posed in chapter one. In this thesis, the 95% level of confidence is attached to all statistical and econometric tests, unless otherwise clarified. After the results are presented, a brief discussion is made about the results and their implication on the study's hypotheses. Tables and other illustrative materials are used to supplement the discussion where applicable.

4.1 Data processing

Data collected from the field was keyed into the computer using The Microsoft® Access 2000 [9.0.3821 SR-1] database package. The choice of this package was made owing to the ease with which data can be processed and the ability to tailor the database program to control for computer operator errors during the processing stage. The database was constructed to control for transcription errors since most of the answers to the household roster and time use sections of the household questionnaire were precoded hence the ability to control for transcription errors when keying in the data. The data tables were subsequently transferred into a spreadsheet (Microsoft® Excel 2000 [9.0.3821 SR-1]) from where further cleaning of the data was possible. There were more than 256 columns in the entire dataset and therefore, it was divided into different files and the questionnaire number retained in each file as the key variable for ease of identifying each record. After data cleaning, all files were sorted with the questionnaire number as the sorting key and saved in a form capable of being read into an appropriate statistical package (©SPSS for Windows, Release 10.0.1). All files were then merged into one file containing all variables for analytical purposes. Frequencies and cross tabulations were performed for categorical data and means were calculated for continuous variables. In this thesis, the 95% level of confidence is attached to all statistical and econometric tests unless otherwise clarified.

4.2 Sample description

The sample was drawn from 66 villages located in the five sub locations. In all households, In total, there were 1,823 people in the 350 households and that for every 100 people, 52 were female.

4.2.1 Household characteristics

The mean household size was 5 persons. The households ranged in size from a maximum of 17 members to a minimum of one member. Most of the households interviewed were represented by more members being over 15 years of age (56 percent of members) with 67 percent of the household members falling under the 24-year bracket while 44 percent of household members were under the 15-year bracket. However, this did not mask the fact that about 17 percent of the household members were within the 5-year bracket. A larger proportion of the population was young and the pyramid tapered off as the ages progress (Table 4.1). Slightly over half of the population was found to be below the 20 year bracket while 30 percent was

under 10 years of age. The household heads had their ages ranging from a minimum of 20 years to a maximum of 95 years while their mean age was 45.8 years.

Most of the households (72 percent) were male headed while the remaining percentage were female headed. Seventy two (72) percent of the household heads were married while 24 percent were widows(ers). In 95 percent of the households, the household head was resident all year round whereas the rest were living elsewhere in at least one of the twelve months preceding the interview. This result probably means that information given about the household was out of direct experience unlike the case if the household head was resident elsewhere hence only providing 'second hand' information about his/her household. The data also revealed that 73 percent of the household heads had attended at least some formal schooling while 70 percent could read a newspaper, 71 percent could write a letter and 70 percent could do written calculations.

Overall, 21 percent of the household heads had no formal education and out of all those who had attended formal schooling, 65 percent had received primary education while 91 percent of these had received some secondary school education. Only one household head had received a university education (0.3 percent). In general, 31 and 24 percent of members in hyacinth free and hyacinth infested areas respectively had not attended any form of formal education. Fifty one percent and 56 percent of household members in hyacinth free and infested areas respectively had attended primary school while 12 and 11 percent respectively had received some secondary education.

From the data, it was possible to establish that 27.7 percent of households were female headed while the remainder was male headed. This figure appears not to be very far off from the figures quoted for the entire county as 36.5 percent.

Table 4: 1 Ages of household members in surveyed households

Age class	Number of individuals in age class	Proportion of total	Cumulative percent
<5	303	0.166	16.6
5-14	507	0.278	44.4
15-24	418	0.229	67.3
25-34	213	0.117	79.0
35-44	160	0.088	87.8
45-54	104	0.057	93.5
55-64	70	0.038	97.3
65++	48	0.026	100
	$\Sigma = 1823$	$\Sigma = 1.000$	

Source: Water hyacinth and household welfare survey, 2000/01

4.2.2 Housing characteristics

From the findings of the survey, there appeared to be no distinct differences between the housing status of households with respect to the area of residence. This was probably a clear indication that these households are indeed comparable since housing is a socio-economic as well as a cultural indicator. Water is an important resource whose availability is fundamental for survival of the human species and its quality and quantity are of special interest. Close to two-fifths (39 percent) of the households draw water for domestic use straight from the lake, nearby streams/rivers or ponds while for another significant number, the domestic water supply source was from wells (table 4:2). The quality of water from the lake may not be very appropriate for drinking unless it undergoes some form of treatment. The food share for households that fetch water from wells with a pump was 0.66 while those that drew water from wells without pumps had a food share of 0.69, an indication that the latter devote a larger fraction of their resources to food and therefore have lower welfare levels. Those households that drew water from rivers, springs or lakes had a smaller food share of 0.66 while those that used rainwater, probably collected into a tank had a food share of 0.64, a probable sign that these households were at a comparatively higher welfare level than all others.

Table 4: 2 Source of water for interviewed households

Source of water for domestic use	Percent reporting source of water		
	<i>Hyacinth free</i>	<i>Hyacinth infested</i>	<i>Total</i>
Others	1	1	1
Public standpipe	1	1	1
Well with pump	22	51	34
Well without pump	5	15	9
River, lake, spring, pond	45	31	39
Rainwater	22	1	13
Missing	3	1	3

Source: Water hyacinth and household welfare survey, 2000/01



Plate 4. 1 A man draws water to sell to the local kiosks from the lake (Usenge, Siaya District)



Plate 4. 2 Notice the green tinge of color in the water, a likely sign of algae rich water (Nyauđenje, Bondo District)

Rainwater was a source of domestic water for about 13 percent the households and this result was not invalidated by the results showing the type of roofing material used by households (table 4:3). Most of the houses (53 percent) were grass thatched while use of galvanised iron was reported by 46 percent of interviewed households and a minor proportion comprising of roofs made from other materials. The food share decreased from grass

(0.69) to galvanised iron sheets (0.64), another probable sign that the long-term welfare levels of the households can be approximated by the type of house they live in. For instance, the amount of monetary outlay that is required to put up grass thatch is much lower than that required to put up galvanised iron sheets. Evident from the results was that a larger proportion of households are of low welfare levels as depicted by the large food share and the number of households living in houses with grass thatched roofs.

Table 4: 3 Material constructing roof

Roofing material	Percent reporting roof type		
	<i>Hyacinth free</i>	<i>Hyacinth infested</i>	<i>Entire sample</i>
Grass	51	53	52
Galvanised iron	44	45.5	45
Concrete/cement	1.5	0	0
Asbestos	0.5	0	0
Missing	3	1.5	3

Source: Water hyacinth and household welfare Survey, 2000/01

Majority of the households (83 percent) live in houses with wood and earthen walls while 78 percent of the floors are earthen (table 4.4) while in a similar manner, few households constructed walls using cement, bricks, stone, wood or galvanised iron. This was true for hyacinth free as well as infested areas. A comparatively small proportion 21 percent of the floors were cemented while the remaining proportion (excluding earthen floor) were either wooden, tiled or made of stone as well as other flooring material (table 4.5).

Table 4: 4 Material constructing wall

Material constructing outside walls	Percent reporting wall type		
	<i>Hyacinth free</i>	<i>Hyacinth infested</i>	<i>Total</i>
Mud brick	3	1	3
Bamboo/wooden planks	1	2	1
Galvanised iron	<1	1	1
Stone/brick	2	2	2
Cement	10	3	7
Mud and wood	80	87	83
Missing	4	3	3

Source: Water hyacinth and household welfare survey, 2000/01

Table 4: 5 Material constructing floor of main house

Material constructing floor	Percentage reporting floor type	
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	<i>Hyacinth free</i>	<i>Hyacinth infested</i>	<i>Total</i>
Earth	75	78	76
Wood	0	1	<1
Stone	0	1	<1
Cement	20	19	20
Tiles	1	0	<1
Other	1	1	1
Missing	3	1	3

Source: Water hyacinth and household welfare survey, 2000/01

Housing can thus be a good indicator of welfare since as it appears from the evidence provided it conforms well to expectations. For instance, comparing the food share between households whose dwelling floors are earthen against those whose floors are cemented, the data revealed that the food share for the latter was much smaller at 0.58 as opposed to 0.69 for the former group⁴⁴. A similar comparison between houses having cemented walls with those that had walls constructed using wood and mud revealed that the food share for the former was still smaller at 0.60 as opposed to the latter group's 0.66, results which show that indeed, housing is a good indicator of living standards. It may be a good measure of long-term living standards than current income or expenditure although the comparison of housing conditions across different areas may be subject to noise since as hinted above, housing also has a cultural dimension to it. The long-term nature of housing however may not provide a clear pointer to short term fluctuations in living standards such as those occasioned by the hyacinth. For instance, from these tables (4.3, 4.4 and 4.5), there appeared to be no distinct differences between hyacinth infested areas and hyacinth free areas in terms of housing conditions. This was probably because these houses were constructed much earlier before the hyacinth invaded the lake. It was observed that households living in grass thatch roofed and mud walled houses had a larger food share than their counterparts besides having lower per capita expenditures. A composite variable, combining grass thatch and mud walls, it was envisioned could be constructed and used as a shifter to the Engel curve up or down, depending on the household's long-term standard of living. Half of the households from the entire sample lived in such houses with infested areas having 49 percent and hyacinth free areas 52 percent respectively.

4.2.3 Main economic activities

Out of the total sample, 1,780 people out of a possible total of 1823 (98 percent) reported their main activities, and 517 (28 percent of total) of these were either students or were too young to work hence, they were not engaged in economic activities. In total, 521 were reported to be formally unengaged in any activity leaving a total of 742 people actively engaged in the labourforce giving rise to a dependency ratio of 1.41 per working person⁴⁵. As the main economic activity of household members, extractive activities (e.g. agriculture, fishing, mining, forestry, mat making, firewood

⁴⁴ Considering that cemented floors are much more expensive to put up than earthen floors.

⁴⁵ Technically therefore, each working person supports 1.41 people.

collection and charcoal burning) accounted for 63 percent of the entire labour allocation displaying the importance of such activities in this area. Agriculture was the main activity for 275 people, that is 37 percent of the labourforce, directly employing 15 percent of the population. Fishing on the other hand employed 24 percent of the total labourforce. Fishing and agriculture were found to be important sources of employment and subsequently, income for the household heads (table 4.6). Both agriculture and fishing were the main economic activities for 61 percent of the working population. Other activities included formal employment, 5 percent of the labourforce and businesses⁴⁶ accounting for 25 percent of the labourforce with the remainder distributed in other minor activities.

Overall, 28 percent of the heads of interviewed households were engaged in fishing and a further 25 percent engaged in agriculture. There was a significant difference between the two areas in terms of whether household heads undertook fishing or not. Only 28 percent of the heads that undertook fishing as their main activity resided in hyacinth infested areas. Households whose heads had fishing as the main activity had a food share of 0.67 while those who were engaged in other activities collectively had a marginally smaller share (0.66) of food in their household budgets. The expenditures in such households were estimated at Ksh 1,784 per adult equivalent per month while for the latter group, this figure was much higher, estimated at Ksh 2,168 per adult equivalent per month. In hyacinth infested areas, mean expenditures between the two groups (fishing and non fishing household heads) were found to be larger for households whose heads did not have fishing as the main economic activity. In hyacinth infested areas however, the food share for 'fishing households' was smaller than that of 'non fishing households'. Comparatively however, the results implied that income generation and therefore household expenditures may have been compromised by the water hyacinth.

Table 4: 6 Main economic activity of household head

Activity	Percent reporting activity			Frequency
	Hyacinth free	Hyacinth infested	Entire sample	
Fishing	34	19	28	98
Agriculture	25	27	25	89
Business	13	21	16	57
Mat making	0	10	4	15
Formal employment	12	3	8	28
'Jua kali'	7	2	5	18
Others	0	2	1	4
Missing	3	9	5	19
None	6	7	6	22

Notes: Fishing includes three fish mongers

Source: Water hyacinth and household welfare survey, 2000/01

⁴⁶ Including *inter alia*, hoteliers, shopkeepers, brewers, tailors, etc.

4.2.4 Household income

It was established that households depended on more than a singular income source. Earnings from formal employment (though accounting for a small proportion of households) were substantially higher than earnings from other income source categories. Household earnings from self-employment were found to be important sources of household income for 49 percent of interviewed households. Earnings from this source averaged Ksh 49,551 annually (table 4.7). Fishing on the other hand contributed an average yearly income of Ksh 41,897 for 47 percent of all interviewed households while agriculture contributed an average of Ksh 19,046 annually for 76 percent of the households. However, only 38 percent of households in hyacinth infested areas derived an income from fishing as opposed to 53 percent in hyacinth free areas⁴⁷. There was also an inverse relationship between water hyacinth presence and whether a household was bent towards fishing as indicated by non-zero fishing incomes. These results therefore led to a strong suspicion (not proven) that this was a reflection of fishermen fleeing from the enterprise hence the comparatively small number of fishing households and the relatively low incomes deriving from fishing activity in infested areas. The available official statistics on fish catches for the specific areas were however unavailable to enable this comparison to be made but this result should be clarified by ongoing research.

Agriculture, though yielding a comparatively smaller income than other activities, was an important source of income for many of the interviewed households judging from the proportion of the sample households deriving incomes from agriculture. Agriculture was an income source for 77 percent of interviewed households while 'self-employment' and fishing were income sources for 50 and 48 percent of sample households respectively. This is also another pointer to the importance of agriculture in the lives of rural dwellers such as those making up the present sample. As will be shown later, food production here is mainly for subsistence purposes since most of the food consumed here was purchased in the market.

Other income sources, which include *inter alia*, pensions, interest on savings, sale of capital equipment etc contributed an average of Ksh 23,816 per year for 49 percent of the households. In total, household annual incomes were estimated to be in the order of Ksh 80,466. When compared across the water hyacinth infested and non infested areas, derived incomes from these income categories in the hyacinth free areas were greater than those in hyacinth infested areas with the exception of income from self employment which was greater in hyacinth infested areas. It was also interesting to note that a good number of sample households derived an income from more than one source. The number of imperfectly correlated income sources available to a household, it is argued is in a way reduces the vulnerability of such a household to external economic shocks resulting from the collapse of some income sources. In this case, fishing, it is assumed was interfered with due

⁴⁷ NB: all these incomes are a cumulation of the value of fish caught whether sold or consumed at home.

to the presence of the hyacinth and through assumed direct and indirect effects and linkages, incomes deriving from this industry were compromised.

Table 4: 7 Mean annual household income from various sources (Ksh/yr)

Income source	Hyacinth free	Hyacinth infested	Entire sample
Formal employment	84,102 (16)	52,840 (3)	80,094 (39)
Self employment	43,355 (43)	56,370 (57)	49,551 (173)
Fishing	43,076 (53)	39,496 (38)	41,897 (164)
Others	25,556 (49)	21,306 (49)	23,816 (171)
Agriculture	22,848 (80)	12,325 (70)	19,046 (267)
All sources	87,755 (--)	69,922 (--)	80,466 (345)

Notes: Other sources include *inter alia* pensions, interest on savings, income from sale and lease of equipment and other capital items. Self employment includes *inter alia*, tailoring, boat making, carpentry, transporting, hotels, kiosks etc. Figures in brackets indicate No. of households reporting income from. The figure in the last column last row does not add up to 350 since 5 households were not willing to volunteer this information.

Source: Water hyacinth and household welfare survey, 2000/01

4.2.5 Household expenditure

Food, as anticipated took the largest share of household income. This was true for the entire sample as well as between the two groups of households—those resident in hyacinth free and hyacinth infested areas. On a per capita basis, households in Busia reported the lowest per adult equivalent expenditure of Ksh 1,294 per month followed by Nyando, Rachuonyo and Migori with Ksh 1,933, Ksh 2,653 and Ksh 2,915 per adult equivalent per month respectively. This result appears to be consistent with the 1997 WMSIII which found that relatively, Busia led the pack in terms of absolute poverty. These expenditures in Busia are found to be lower than the overall poverty line for rural areas in 1997 which was estimated at Ksh 1,239 per adult equivalent per month (ksh 1,452) after adjusting for inflation. Compared to the other expenditure categories, education, health and ceremonies represented a substantial fraction of the remaining expenditure.

Statistical tests (t tests) were performed and showed that mean income and expenditure were significantly different from zero and from each other. Household income was found to trail household expenditure. This was in line with the results of many developing country household surveys where there is a significant understatement of incomes and/or an overstatement of expenditures. This observation is not just confined to developing countries but developed countries too where most of the income derives from formal employment which is more easy to track seem to display the same kind of pattern (Deaton, 1997). In this case, like in numerous studies before, there were 'negative' savings. Therefore, it is evident that much as there is a

natural tendency to think of the residual between income and expenditure as savings, this may not be the case.

These 'negative' savings were probably because households either knowingly or unknowingly gave erroneous responses especially when asked to account for their incomes. It could as well be because income, especially annual household income is at best only a normative estimate and subject to great variation over time. Various reasons for understating incomes have been envisaged ranging from fear of taxation to fear of disclosing illegal or dubious activities. These seasonal incomes sometimes from the one-off or infrequent income generating activities are unlikely to be picked up by a household survey with an annual frame of reference (Johnson, McKay and Round, 199?).

In the overall sample, household annual expenditure was estimated to be Ksh 96,407 while income was estimated as Ksh 80,466 (table 4.8). Incomes appear to be more subject to underreporting than expenditures are to higher claims. In addition, reported expenditures had a coefficient of variation that was much lower than that of household income i.e. 83.8 percent as opposed to 143.2 percent in the case of income. This justifies the use of expenditure as an income proxy in the Engel curve as the spread in the chosen exogenous variable is minimized reducing potential heteroscedasticity during OLS estimation. Estimates of household expenditure just as incomes were lower in hyacinth infested areas. Between the two areas, mean annual household expenditure was estimated as Ksh 77,199 in hyacinth infested areas as opposed to Ksh 109,676 in hyacinth free areas.

Expenditures in hyacinth infested areas were consistently smaller for all the expenditure categories appearing on table 4.8 with the exception of ceremonial (wedding and funeral) expenditures. Results on table 4.7 above show a similar trend with the exception of income from self employment which is composed of *inter alia*, small businesses—tailoring, boat making, carpentry etc which were income sources for 50 percent of sample households.

Table 4: 8 Mean annual household expenditure in hyacinth free and infested areas (Ksh/yr)

Expenditure item	Hyacinth free	Hyacinth infested	Entire sample
Food expenditure	69,055	45,821	59,502
Education	7,703	5,284	6,720
Fuel	8,164	5,580	7,096
Health	6,537	3,889	5,452
Clothing	3,982	3,117	3,627
Ceremonies	2,718	3,646	3,098
Others	11,554	9,615	10,757
Total household expenditure	109,676	77,199	96,407

Notes: ceremonies include expenditure on funerals, dowry etc.

Source: Water hyacinth and household welfare survey, 2000/01

Looking at the shares for food, hyacinth free areas had a mean share of 0.67 while hyacinth infested areas reported a mean of 0.65 on food (table 4.9). Rice, wheat, sorghum and millet account for a combined 12.9 percent and 11.3 percent of expenditure in hyacinth free and hyacinth infested areas respectively. Maize accounted for a comparatively large share of expenditure commanding about 28 percent and 26 percent in the two areas respectively. These translate into 40-43 percent of all food expenditure being devoted to maize grain only. This seemed plausible since previous study results showed that households in South Nyanza and Western Provinces allocate 39.7 and 38.5 percent of their expenditure respectively on grains where millet, sorghum and maize dominate the diet in these Provinces (Greer and Thorbecke, 1986).

Fish another major component of the lakeshore diet took up about 16.6 percent of expenditure in the hyacinth free areas while in hyacinth infested areas, the share of fish in total expenditure was much lower at 9.9 percent. The presumably large difference in fish consumption between these two areas was due to water hyacinth as observed elsewhere in this thesis and in an earlier study by Okallo (1999). The water hyacinth was by large opinion disastrous to fishing. There was neither evidence nor reason to believe that this was a reflection of forces other than the shortage of fish as a result of low fish catches and/or high prices caused by hyacinth blocked landing beaches. However, a related study making use of time series data is underway to establish the exact relationship between fishing, fish catches and water hyacinth infestation and hopefully, this study will shed more light into the issues involved. Besides the food share, health expenditures accounted for an almost similar proportion in both hyacinth infested and free areas.

Table 4: 9 Expenditure shares for different items in hyacinth free and infested areas.

Expenditure Item	Hyacinth free		Hyacinth infested	
	<i>Mean</i>	<i>Standard deviation</i>	<i>Mean</i>	<i>Standard deviation</i>
Food	0.67	0.17	0.65	0.18
(f) Beans	0.03	0.02	0.05	0.04
(f) Cereals (Maize grain & flour)	0.28	0.17	0.26	0.14
(f) Fish	0.17	0.13	0.10	0.07
(f) Maize flour	0.17	0.13	0.22	0.16
(f) Maize grain	0.15	0.22	0.06	0.09
(f) Rice	0.04	0.03	0.06	0.03

Expenditure Item	Hyacinth free		Hyacinth infested	
(f) Sugar	0.09	0.06	0.11	0.07
(f) Vegetables	0.06	0.04	0.05	0.04
(f) Wheat flour	0.03	0.06	0.03	0.06
(f) Sorghum & millets	0.06	0.04	0.03	0.03
Ceremonies	0.02	0.04	0.04	0.07
Clothing	0.03	0.03	0.03	0.04
Education	0.05	0.09	0.05	0.09
Health	0.05	0.07	0.05	0.08
Fuel	0.07	0.06	0.07	0.06
Others	0.09	0.08	0.11	0.09

Notes: The shares may not add up exactly to 100% due to rounding. (f) stands for food.

Source: Water hyacinth and household welfare survey, 2000/01

4.2.6 Food expenditure characteristics

The data revealed that over half of all food consumed was acquired through cash purchases. This implied that the subsistence orientation of agriculture in such areas is not as strong as in other areas where only a small proportion of food consumed is purchased. For instance, over 60 percent of maize, 70 percent of fish, all of the rice and sugar consumed are purchased. This pattern holds the water hyacinth infestation notwithstanding. With respect to hyacinth infested areas, 55 percent of all food consumed was from cash purchases while in hyacinth free areas, this figure was higher at 64 percent.

In addition, the present study also revealed that grains (specifically maize) are important food sources as column 5 of table 4.10 shows. More households consumed maize during the reporting period of one week than those that consumed sorghum and millet for example. In addition, the amount of money spent on maize was higher than that spent on any other individual food item. 'Traditional' grains such as sorghum and millet were not as popular as maize. This is a reflection of changing demand-supply conditions over time probably occasioned by policies that give an overriding priority to maize as a commodity as opposed to 'traditional' crops such as millets, sorghums, cassava, etc. Under such circumstances, policies designed at altering the nutritional standards (as far as starchy staples are concerned) of the poor should target more on food grains such as maize, unless of course a shift in consumer tastes occurs in the interim. The place of starchy staples such as sweet potato and cassava also stuck out prominently as another important source of nourishment for interviewed households. Previous study has shown that on comparing the food consumption pattern of the poor and the rich, the former obtain a significantly larger proportion of their calories from grains than the non-poor (Greer and Thorbecke, 1986). This result has fundamental implications for poverty alleviation, especially in view of the fact that a significant proportion of the rural population is classified as poor. It should be remembered that this study was done on rural dwelling households.

Fish is also an important ingredient in household diets. This is so, judging from the number of households that had consumed fish at least once during

the 12 months preceding the interviews. The amount of money devoted to fish ranks second overall behind maize. It therefore appears that fish is more important in the diets of surveyed households than comparable animal protein sources such as beef, mutton, poultry meat or even milk and eggs. An important implication of this result is that as much as possible, care should be taken to ensure the sustainability of this protein source. However, this should not be a reason to be oblivious to the place of plant derived proteins such as those from beans which is probably the second most important protein source for sample households.

Although the proportion of fish acquired in cash does not differ across the two areas, the amount of money allocated to fish expenditures is higher in hyacinth free areas. This is probably as a result of hampered fish supplies in hyacinth infested areas. It could also mean depressed fish prices hence the seemingly low cost of acquiring fish supplies or the relatively low fish prices of non commercial fish catches such as mudfish which were common in some of the areas e.g. Kusa beach in Nyando district. A spot check revealed that prices of commercial fish species were almost standard irrespective of whether the area was hyacinth infested or not. In hyacinth infested areas, households that earned fishing incomes purchased 42 percent of fish consumed while those that did not earn fishing incomes purchased 87 percent of the fish consumed. In hyacinth free areas on the other hand, those households that earned fishing incomes purchased 47 percent of the fish consumed while those that did not earn fishing incomes purchased 91 percent of fish. Households in hyacinth free areas it appeared consumed more fish than those in hyacinth infested areas. With hyacinth infestation, the amount of money spent on fish is small even for households that earn incomes from fishing.

Table 4: 10 Household food basket expenditure characteristics in hyacinth infested and free areas.

Food item	Hyacinth free		Hyacinth infested		Entire sample		
	%	Ksh	%	Ksh	N	%	Ksh
Rice	100	79	96.5	61	212	98	69.80
Maize grain	66	114	74	42	237	67.6	90.80
Maize floor	74	234	83	178	239	77	227.8
Wheat floor	100	57	98	68	170	98	57.00
Fish	71	193	72	74	262	68	160.5
Sugar	100	127	100	108	250	100	116.0
Vegetables	68	70	55	36	260	61	59.00
Cooking fat	100	55	100	74	244	99.6	61.70
Tea leaves	100	21	100	11	224	99.8	18.00
Beans	73	58	67	31	222	68.9	49.00
Tomato, onions	77	97	72	35	219	71.6	68.90

Food item	Hyacinth free		Hyacinth infested		Entire sample		
	%	Ksh	%	Ksh	N	%	Ksh
Yams, potato	64	42	72	43	219	62	41.00
Bread	100	78	100	40	189	100	65.00
Cassava	88	76	80	28	186	81	53.80
Milk	76	103	73	52	186	71	88.00
Banana (ripe)	97	33	86	16	178	90	24.00
Poultry meat	56	37	40	41	174	36	36.00
Beef, mutton	99	57	94	39	166	94	50.80
Millet	88	94	76	34	128	76	60.80
Eggs	82	28	45	14	127	54	22.40
Sorghum	69	95	80	12	122	68	49.80
Banana (cooking)	99	47	81	17	107	85	31.80
Peanuts	86	30	77	14	105	69	20.70
Alcohol	90	187	98	53	83	94	129
Coffee	100	28	97	6	68	95	13.70
Soft drinks	100	35	100	22	64	96	32.00
Ghee	79	71	74	20	64	61	54.70
Carrots	100	12	99	2	47	91	2.30
Dishes away from home	100	138	100	20	43	99	60.70
Honey	100	125	100	8	27	100	12.00

Notes: % refers to the mean percent of food [ITEM] normally acquired in cash, Ksh is the amount of money the food consumed in one week by the responding household was worth. N is the number of households that had consumed the food [ITEM] in the 12 months preceding the interview.

Source: Water hyacinth and household welfare survey, 2000/01

4.2.6 Adequacy of consumption

To complement the 'microeconomic welfare assessment' households were asked to assess their consumption needs and rate them according to whether they were adequately met or not. Most needs of the households across the board were inadequately met as results table 4.11 show. There seemed to be an emerging trend that a slightly larger proportion of households in hyacinth infested areas were not able to satisfy their food, shelter, clothing, health and educational requirements adequately. These results imply that in hyacinth free areas, more households were satisfied with their lives than in hyacinth infested areas. Over 59 percent of households in hyacinth free areas were unable to adequately meet needs while in water hyacinth infested areas, the percentage of such disadvantaged households was over 69 percent.

In particular, over 78 percent of surveyed households appraised their incomes to be at a level, not sufficient for them to meet their minimum consumption requirements. As a whole, ability to meet basic requirements

seemed limited since, consistently, well over half of the surveyed households did not adequately meet their needs. For instance, a significantly larger proportion (72 percent as opposed to 57 percent) of households in hyacinth infested areas averred that food needs were inadequately met. This result tallied with the finding that households in hyacinth infested areas allocated less resources (in absolute terms) to food.

The results of this self evaluation served to gauge how the sampled households viewed their welfare. It provided a pointer to the hypothesis that the hyacinth reduced household welfare as the results in the following sections further imply. The inadequacy especially of food consumption for over half of the interviewed households—their status vis-à-vis the hyacinth notwithstanding—implied that these households could be considered food poor and hence insecure. Interestingly, the food share of 63 percent of the households (those that considered food consumption to be less than adequate) was 0.65 while that of the remaining came to 0.67, figures which were not statistically different. Interestingly too, households in hyacinth free areas that didn't consider their consumption to be adequate reported a larger food share of 0.67 as opposed to 0.62 for those in hyacinth infested areas. For households that considered their consumption of food just adequate, the food share was 0.67 in hyacinth free areas and 0.66 in hyacinth infested areas.

Table 4: 11 Households self evaluation of consumption adequacy, (percent of households)

	Adequacy	Food	Housing	Clothing	Health	Schooling	Income
<i>Hyacinth</i>	Not adequate	65	70	70	69	59	78
	Just adequate	34	30	30	31	30	19
	More than adequate	1	0	0	0	1	2
	Not applicable	0	0	0	0	11	1
<i>Hyacinth</i>	Not adequate	82	73	89	79	69	84
	Just adequate	17	25	11	16	17	15
	More than adequate	1	2	0	3	0	0
	Not applicable	0	1	0	2	14	1

Notes: Adequate means no more nor less than what the respondents consider to be the minimum consumption needs for the household.

Source: Water hyacinth and household welfare survey, 2000/01

4.2.7 The food share and water hyacinth

Weekly expenditures on all food items that expenditures were inquired about were summed to produce a household total from where it was possible to estimate the share of food in total expenditure for individual households. There were 31 listed food items in total (see sample questionnaire in appendix for details) and blank rows to accommodate up to 29 more different foods. The WMSIII contained 17 categories of foods with almost 79 sub categories while the present survey inquired about a maximum of 60 categories per household. The average food share for rural Nyanza in 1997 was estimated to be 0.79 while in Western province, this was estimated at

0.764 (table 4.12) hence the figures used to test whether the food share had changed between 1997 and the time of this survey. A t test was performed and it was concluded that the average food share calculated from the WMSIII data was different from the average food share from the current survey. It was also concluded that the mean food share was significantly different from the food share in rural areas estimated as 0.717 for the whole country.

Whether these results reflected real changes in the food share between the two periods or differences in questionnaire design cannot be answered at this stage however. Whichever the case, the current study's estimated food share was lower than that estimated in 1997 and if this is a true reflection of improved welfare, then it may be said that the period—1997—prior to this study may have been more constraining. It is important to note that this was during a time when the hyacinth infestation was close to its peak as opposed to the 2000/01 period during which the study was undertaken since media and other reports as well as occasional spot checks showed an appreciable drop in hyacinth infestation levels. It may have as well been due to an improved ability to cope with the weed with the passage of time.

Table 4: 12 Means test for differences in food share between 1997 and 2001

Region	WMSIII 1997 ^a	Water hyacinth survey, 2001	T statistic
Nyanza Rural	0.79	0.6649	-11.346
s.e of mean		1.103×10^{-2}	
d.f.		225	
Western Rural	0.764	0.6586	-6.157
s.e of mean		1.711×10^{-2}	
d.f.		123	

^a Adapted from Republic of Kenya, 2000, Annex table 3b, p58. (s.e.) is the standard error of mean and d.f. denotes the degrees of freedom

The average food share in hyacinth infested areas was 0.65 (table 4.13) while in hyacinth free areas, it was computed as 0.67. For the entire sample, the food share was 0.6627. A one-way ANOVA procedure was used to test for homogeneity of variances between hyacinth infested and hyacinth free areas. The calculated F value was checked against the critical value and it was concluded that variances were equal. This suggested that the food shares came from the same population. Following the result of the F test, a student t test was performed to test whether the difference in the food share between the two areas was significant. The computed t was 1.542 which led to the conclusion that the food share was not significantly different between the two areas.

Table 4: 13 Food share characteristics between the two areas

Statistic	Hyacinth free	Hyacinth infested	Entire sample
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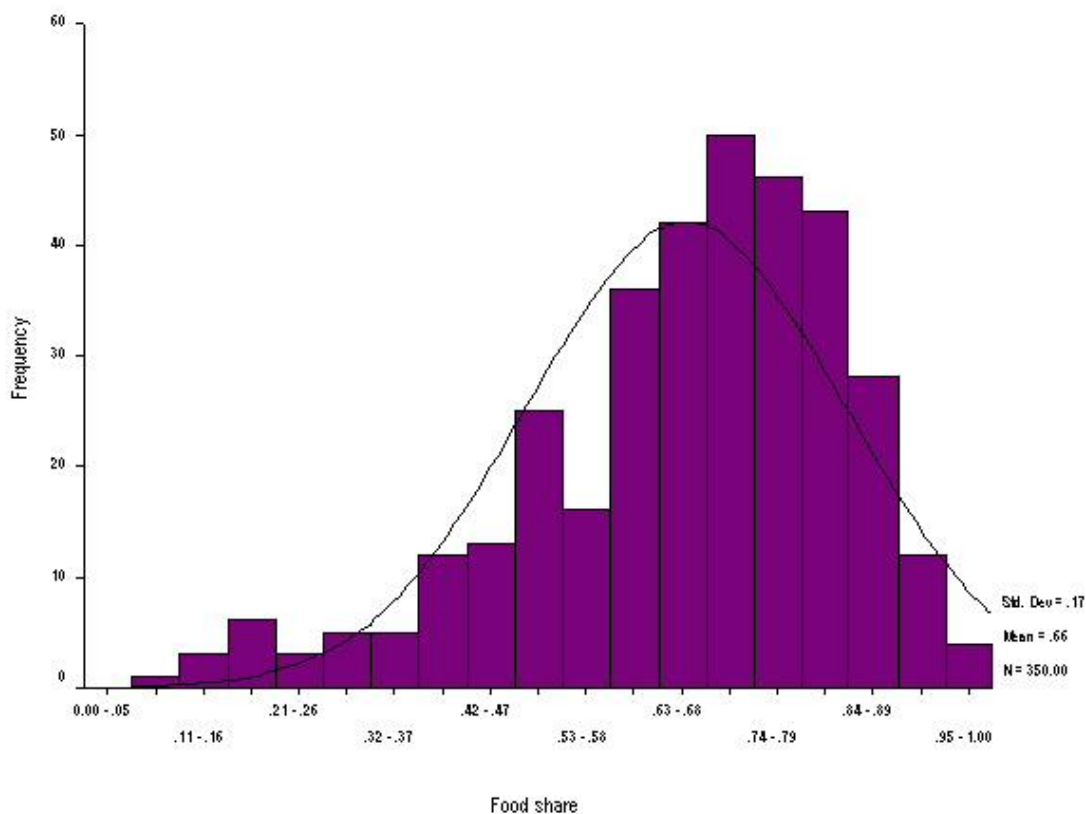
Statistic	Hyacinth free	Hyacinth infested	Entire sample
Mean	0.6746 (0.0117)	0.6454 (0.0153)	0.6627 (0.0093)
Skewness	-0.941 (0.169)	-0.748 (0.203)	-0.86 (0.13)
Kurtosis	1.127 (0.337)	0.195 (0.403)	0.663 (0.26)
Percentiles			
10	0.4673	0.3946	0.4204
20	0.5546	0.4880	0.5218
25	0.5939	0.5169	0.5663
30	0.6091	0.5517	0.6049
40	0.6554	0.6397	0.6514
50	0.7001	0.6967	0.6969
60	0.7325	0.7188	0.7298
70	0.7772	0.7593	0.7704
75	0.7976	0.7811	0.7887
80	0.8119	0.8038	0.8085
90	0.8719	0.8461	0.8504

Notes: Figures in brackets are standard errors

Source: Water hyacinth--household welfare survey, 2000/2001

A histogram derived from the data (figure 4.1) showed that the distribution of food shares was negatively skewed. Most households reported a large food share relative to the number of households that reported a small food share. For instance, 90 percent of the observations of the food share are greater than 0.5796 whereas, in only 10 percent of the observations was the food share equal to or less than 0.1496. Half the sample households allocated more than half of their expenditure to food. This, as well as the negative correlation ($r=-0.307$) between the food share and annual expenditure was an indication that most of the responding households could be considered poor, at least from Engel's Law. The fact that the distribution of food shares was negatively skewed despite the area of residence—whether infested or not—suggested that the hyacinth was not particularly responsible for such a distribution. However, the distribution of food shares in hyacinth free areas was more skewed implying a greater departure from symmetry.

There was also a positive kurtosis implying that the observations cluster more and have longer tails than those of a normal distribution. The coefficient of kurtosis was greater in hyacinth free areas than in hyacinth infested areas.



Source: Water hyacinth and welfare

survey, 2000A1

Figure 4: 1 Histogram showing the distribution of food shares

From the expenditure data provided, it was possible to group household expenditures into seven non overlapping groups namely; food, clothing, health, education, fuel and ceremonies while the remaining expenditures were lumped into one group--others. Expenditure shares were then computed and it was established that food took up more than all other items combined (over 60 percent) while education and health took up about 10 percent of household budgets. There did not appear to be a pattern peculiar to either of the areas studied. Ceremonies and clothing took a combined 2-4 percent while other expenditures made up the remainder. Figures 4.2 and 4.3 represent shares of expenditure categories for households living in the two regions—water hyacinth free and hyacinth infested areas respectively.

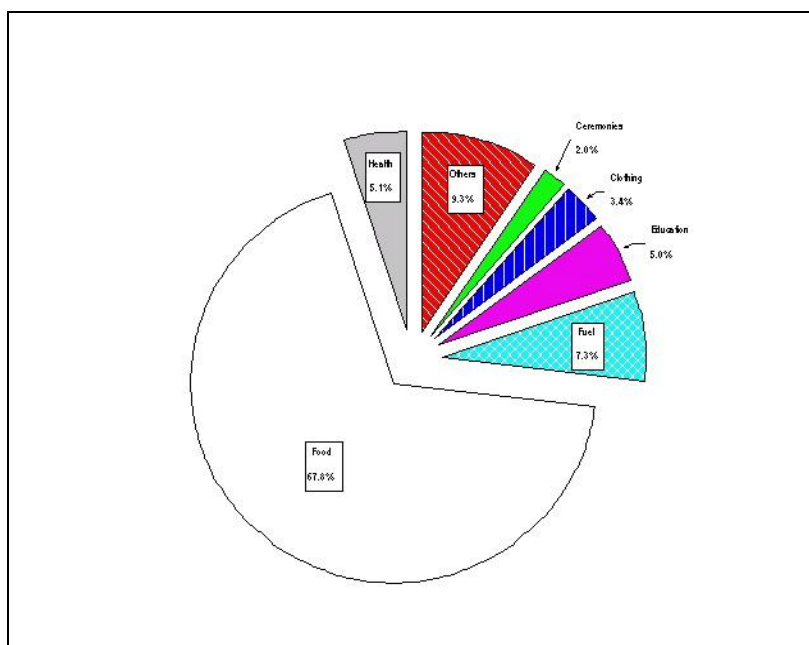


Figure 4: 2 Household expenditure shares for different items in hyacinth free areas

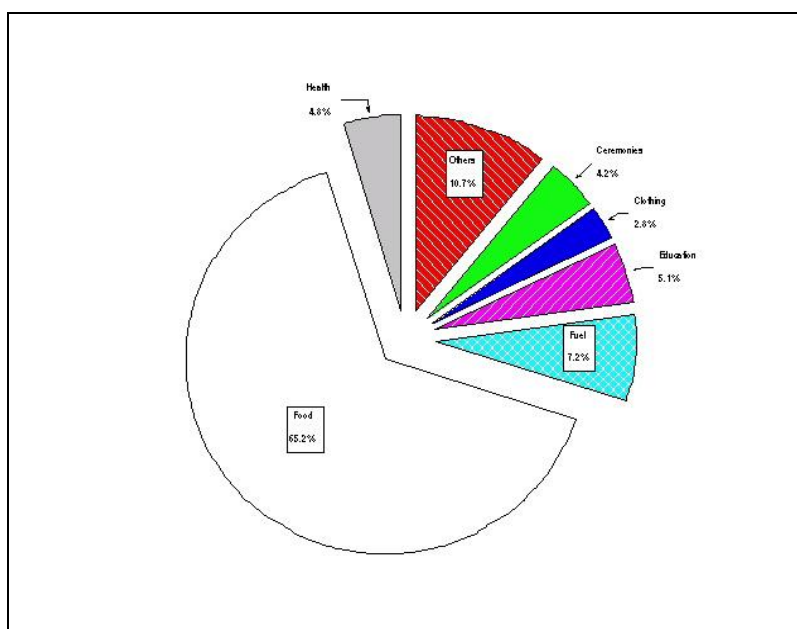


Figure 4: 3 Household expenditure shares for different items in hyacinth infested areas.

The poverty lines developed from the 1997 WMSIII were adopted as the cut-off points used to classify households as poor or not. The implied measure of poverty is absolute since it attaches a real value over time and space guaranteeing that comparisons made are consistent in the sense that

households with the same level of welfare are treated the same. The WMSIII had three classes of households depending on which side they lied with respect to the poverty lines developed. The food poverty line indicates the minimum expenditure on food sufficient to meet the FAO/WHO recommended daily allowance of 2,250 calories per adult per day. The food poverty line in 1997 was estimated as Ksh 927 per adult person per month in rural areas. The overall poverty line was derived after an allowance was allowed for non food expenditures for rural areas, which was estimated as 1,239 per adult equivalent per month in 1997. The hardcore were described as that group that were unable to attain the minimum 2,250 calories per adult person per day even if expenditure was devoted entirely to food.

Keeping in mind the span of time between the WMSIII and the present survey, these poverty lines were transformed in order to make them comparable with data from the current study. To transform them, the inflation rates of 6.6, 3.5 and 6.2 percent during the years 1998, 1999 and 2000 were used. The transformation yielded current equivalent poverty lines of Ksh 1,086 and Ksh 1,452 per adult equivalent per month as the food poverty and overall poverty lines for the current data.

From the data, it was noticed that all households falling below the food poverty line were also hardcore poor since allocating all available expenditures to food would not see them attain the minimum food requirements. Therefore, any reference to hardcore poverty in this thesis will be referring to food poor households too. Using these calibration points, 42 percent of the sample households were classified as being overall poor, meaning that given their resources, they could not afford some of the necessities of life (see table 4.14). In total, 29.5 percent of the sample households did not have enough resources to enable them attain the FAO/WHO recommended minimum 2,250 calories per day per adult person. In hyacinth infested areas, 36.2 percent of the sample households were classified as being food poor or hardcore poor while 24.9 percent of sample households from hyacinth free areas were classified thus. Similarly, 55.1 percent of sample households were classified as overall poor in hyacinth infested areas against 33.3 percent in hyacinth free areas. This showed that 44.9 percent of sample households in hyacinth infested areas were classified as non poor as opposed to 66.7 percent in hyacinth free areas.

Table 4: 14 Distribution of welfare classes in hyacinth free and hyacinth infested areas

Welfare group	Percentage of households falling within welfare group		
	<i>Hyacinth absent</i>	<i>Hyacinth present</i>	<i>Overall sample</i>
Hardcore poor	21.3	32.2	25.7
Food poor	15.5	32.2	22.3
Overall poor	1.4	1.4	1.4
Non poor	61.8	34.3	50.6

Total	100	100	100
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Source: Water hyacinth--household welfare survey, 2000/2001

In hyacinth infested areas, the hardcore poor had a food share of 0.66 while in hyacinth free areas, the food share was 0.70 with the two groups having per adult equivalent monthly expenditures of Ksh 796 and Ksh 776 respectively (table 4.15). The overall poor on the other hand had a food share of 0.81 in hyacinth infested areas and 0.79 in hyacinth free areas. The per adult equivalent monthly expenditures for this category of households were Ksh 1,273 and Ksh 1,338 in hyacinth infested and hyacinth free areas respectively. The non-poor on the other hand had their expenditures averaging Ksh 2,575 and Ksh 2,979 in the two areas respectively. The food poor however appeared to have lower food shares; 0.54 and 0.53 in hyacinth infested and hyacinth free areas respectively.

Table 4: 15 Monthly adult equivalent expenditures in hyacinth infested and hyacinth free areas

	Welfare group	Hyacinth free	Hyacinth infested	Overall sample
Total monthly expenditure per adult equivalent & (food share)	Hardcore poor	776.5 (0.70)	796.0 (0.65)	786.5 (0.68)
	Food poor	1,826.5 (0.53)	1,678.4 (0.54)	1,739.2 (0.54)
	Overall poor	1,337.9 (0.79)	1,272.7 (0.81)	1,311.9 (0.80)
	Non poor	2,979.1 (0.70)	2,574.8 (0.73)	2,867.2 (0.71)

Notes: Figures in brackets are food shares.

Source: Water hyacinth--household welfare survey, 2000/2001

4.2.8 Household asset ownership

Households were asked about the ownership of different assets ranging from radios sewing machines, from boats and land to motor vehicles. It was noticed that households over half the number of sampled households owned items such as charcoal 'jikos', land, livestock radios and household furniture as can be deduced from table 4.13 below. Most (70 percent) of the interviewed households owned land while 63 percent owned livestock. With respect to fuels it appeared that more households (67 percent) used charcoal stoves as opposed to 43 and 3 percent who reported owning kerosene and gas stoves respectively. More households owned fishing gear than the number of households owning fishing boats. Only 22 households reported owning both boats and fishing gear. The results also indicated that out of the 92 households that owned fishing gear, only 42 owned a boat. Therefore, non-boat owning fishgear owners borrowed boats from boat owning households or that they lent out their nets to others or a combination of these. Of the 64 boat owners, only 34 percent owned fishing gear. It was therefore evident from the data that ownership of a boat did not guarantee one to own fishing gear or vice versa. The result appears plausible since it was established that boat owners and gear owners do at times lend out these

equipment. For those households that either owned a boat or fishing gear, a larger percentage (45 percent) owned both boats and gear in hyacinth free areas as compared to 14 percent in hyacinth infested areas. In a similar fashion, a larger proportion (72 percent) in hyacinth infested areas owned gear as opposed to half this proportion in hyacinth free areas.

Oxploughs were reportedly owned by 17 percent of sampled households. Out of 59 households owning oxploughs, 93 percent had livestock meaning that only 7 percent owned oxploughs but not livestock. This indicated the principal determinant of owning an ox-plough was the ownership of livestock, with an equally great likelihood of owning oxen. In addition, over all households owning land, livestock or oxen, there was a larger probability of owning a combination of land and livestock. A likely pattern therefore appeared to emerge from the allotment of asset ownership. As opposed to the complementarities in agriculture--plough ownership and livestock ownership--fishing seems to be characterised by substitutions in asset ownership--boat ownership and fishing gear ownership.

In relation to asset ownership, households were asked to attach a value to how much they would sell each of the listed items that they owned. This acted as a rough estimate of the present value of the asset and summing over all assets owned by the household, a value was derived to serve as an estimate of each household's present value of all assets. The mean value of physical capital owned by the households was Ksh 97,331 over the whole sample. In hyacinth free areas the value of assets was estimated at Ksh 94,983 and Ksh 101,162 in hyacinth infested areas.

It also emerged that households were much more likely to sell livestock first before they considered fishing gear or boats in times of urgent liquidity needs (table 4.16). They also were likely to sell off radios, land, bicycles, stoves before considering to sell off their fishing equipment. The items that would be sold first were most probably those that did not earn households an income i.e. This may confirm comments made about the inability of lakeshore communities to shift from fishing since it is a way of life and also that alternative activities such as agriculture are not as attractive.

The relationship between physical capital and the food share was found negative. This correlation was significant. However, the value of household physical capital and food expenditure per capita was positive but not significant. There was a significant correlation between the value of physical capital and household expenditure. These correlations were apparent, hyacinth status notwithstanding.

Table 4: 16 Household asset ownership in the two areas

[ITEM]	Percent owning asset			Percent likely to dispose [ITEM] first
	Hyacinth free	Hyacinth infested	Entire sample	

[ITEM]	Percent owning asset			Percent likely to dispose [ITEM] first
	Hyacinth free	Hyacinth infested	Entire sample	
Bicycle	55	27	44	11
Boats	27	6	18	5.6
Carts	7	--	4	8.3
Fishgear	32	17	26	5.7
Gas	4	1	3	--
Charcoal	69	66	67	57.4
jiko				
Land	71	70	70	12.2
Livestock	70	55	63	22.1
Ox plough	23	8	17	--
Radio	80	61	72	17
Sew machine	6	4	5	6.7
Sofa	52	68	59	9.7
Kerosene stove	43	44	43	17.3
TV	9	6	8	6.3
Wheelbarrow	16	15	16	8.6

Source: Water hyacinth--household welfare survey, 2000/2001

4.2.9 Social capital and household outcomes

Households were asked to report on the number of transactions between them and members of other different households within the last twelve months preceding the survey. In addition, they were also asked to state the value in Ksh of these transactions. A household's social capital was defined as the number of cash transactions between the household and members of other households. The number of individual transactions ranged from none to a maximum of nine (table 4.17). Successively fewer and fewer households had more social capital i.e. more households had fewer transactions—social capital—and hence, it appears that social capital is probably just as scarce as other 'traditional' forms of capital.

Table 4: 17 'Social capital' and the food share

Index of social capital	Percent reporting 'social capital' and (mean food share)		
	<i>Hyacinth free</i>	<i>Hyacinth infested</i>	<i>Entire sample</i>
0	20 (0.72)	22 (0.68)	21 (0.70)

1	21 (0.70)	24 (0.65)	23 (0.68)
2	22 (0.67)	24 (0.65)	23 (0.66)
3	14 (0.67)	15 (0.65)	15 (0.66)
4	13 (0.63)	4 (0.70)	9 (0.64)
5	6 (0.66)	6 (0.53)	6 (0.61)
6	<1 (0.35)	3 (0.50)	1 (0.47)
7	1 (0.47)	1 (0.52)	1 (0.49)
8	<1 (0.71)	--	<1 (0.71)
9	1 (0.40)	--	1 (0.40)

Notes: Figures in brackets are mean food shares for respective groups.

Source: Water hyacinth--household welfare survey, 2000/2001

There appeared to be a pattern indicating that households with more social capital were those that are better off since the food share and social capital were negatively correlated ($r = -0.217$), a correlation that was statistically significant. For instance, households that interacted with only one other household over the previous year had a food share of 0.69 while those with two, three and four transactions reported a food share of 0.66, 0.66 and 0.54 respectively. Social capital was also negatively correlated with household per capita expenditure and the correlation ($r=-0.213$) was statistically significant. Social capital was as anticipated, positively correlated with household expenditure with a correlation coefficient of 0.155 a correlation that was statistically significant. Social capital was also positively correlated (though not significantly) with expenditures on ceremonies such as funerals and dowry, which are in most part, social expenditures. This positive correlation is probably a reflection of the association between the number of ties between different households and therefore, the number of potential obligations that these ties entail. Household ceremonial expenditure is positively correlated with its per capita expenditure and negatively correlated with the food share which helps complete the picture where, it is possible to observe the place of social capital and other household outcomes.

It was worth noting that the communities living next to the lake were not passive observers of the hyacinth's impact. For instance, through communal effort, the fishing community in organised to have a clear pathway into the lake by creating a small channel leading into the clear lake (plate 4.3) through which boats could access dry ground. This is one of the strengths of social capital since it can be seen that fishermen trusted their colleagues would contribute to such an activity which was successfully accomplished.



Plate 4. 3: A channel cleared of water hyacinth to pave way for boats (Kusa beach, Nyando District)

4.2.10 Household remittances

From the data, about 60 percent of the households were involved in interhousehold transactions. In water hyacinth infested areas, households appeared to receive more than they were able to lend. This can be explained intuitively as being caused by low incomes in these areas, which may translate into greater credit requirements (table 4.18) to help smooth consumption. Such informal credit, which other studies have shown (see Mailu *et.al*, 1998) is usually devoted to consumption smoothing, as opposed to production indicates a paucity of formal credit for this purpose. The difference between what households received and what they gave was quite large and negative--they appeared 'owe' more than they were 'owed' while in hyacinth free areas, this difference was positive and smaller—they were 'owed' rather than 'owed' others.

Over 70 percent of the transactions were however between relatives and thus the credit market seemed to have been composed of participants characterised by horizontal connectedness. Thus, the likelihood is that these relationships are not client-patron relationships but more of 'friendship ties'. It could as well mean that the close dependence on relatives for 'credit' needs was a reflection of a credit rationed market as most of the available credit did not find itself moving between individuals without direct kinship ties⁴⁸. Its heavy presence among kin served as an indication of low transaction costs since information asymmetries are minimal while it maintains an inbuilt mechanism to ensure compliance.

⁴⁸ Assuming that available assistance is first given to those 'closest' to a donor and any other persons come in a close second.

Some of the characteristics of such informal lending and borrowing that ensure its commonness are its diversity, liquidity, security and its low transaction cost. This result is a good indicator of the presence and functioning of social capital whose central pillar is that of trust, which can be argued, to be more enhanced in kin-kin relations than that found in more formal transactions. The results also revealed that whereas in hyacinth free areas 32 percent of assistance came from relatives, only 8 percent came from this source in hyacinth infested areas. A simple explanation of this state of affairs is that as argued above, low incomes during hyacinth infestation meant a lowered lending portfolio leading to credit rationed non-kin. The finding that most of the recipients and donors are resident in a rural area suggested that these transactions take place between people who are geographically close to each other and not spatially distant entities.

The fact that households in hyacinth infested areas seem to receive a larger amount of money than those living in non infested areas and that these are from relatives living in a rural area, most probably in the same village seems to be counterintuitive if not paradoxical. One question emerging here was; where did the money lent to households in hyacinth infested areas come from? This could be illustrated partly by table 4.18, which reveals that 'fishing households' (head has fishing as main occupation) give and receive less than other households in non-infested areas. Two related strands of reasoning then emerge. Firstly, it may have been due to the fact that the credit worthiness of 'fishing households' was compromised by their low incomes and thus, were able to command less assistance than 'non fishing households'. This is why 'fishing households' showed less remittance. Secondly, it could have been that households in infested areas lent from previous savings or were forced to cut on expenditure to build on their lending portfolios or that the remittances that 'fishing households' got from relatives were derived from sources other than fishing such as past savings. In non-infested areas, 'fishing households' appeared to lend more than they borrowed.

To take the analysis a step further, when in the place of occupation of the household head (fishing vs. non fishing) the earning of non zero fishing income was used to compare households, the same pattern repeated itself. Households that earned fishing incomes—hereby fishing households—still borrowed more than they gave. In addition, households in water hyacinth infested areas lent less than in hyacinth free areas.

Table 4: 18 Remittances to and from sample households

Item	Hyacinth free	Hyacinth infested	Entire sample
Number of households	207	143	350
Total number of donations/assists	245	136	378
Number of households donating	131	83	216

Item	Hyacinth free	Hyacinth infested	Entire sample
% of donations to relatives	65.5	83.1	71.7
% of donations to non relatives	35.5	16.9	28.3
Mean value of donations (Ksh)	3,927	1,948	3,148
Total number of receipts	209	137	344
Number of households receiving assistance	125	86	210
% of assistance from relatives	68.4	91.9	77.6
% of assistance from non relatives	31.6	8.1	22.4
Mean value of assistance (Ksh)	3,600	9,280	5,910
Mean value of donations made by fishing households (Ksh)	1,939	842	1,665
Mean value of donation made by non fishing households (Ksh)	2,700	2,294	3,843
Mean value of assistance received by fishing households (Ksh)	1,435	6,055	2,612
Mean value of assistance received by non fishing households (Ksh)	4,652	10,609	7,269

Source: Water hyacinth and household welfare survey, 2000/01

To explore the issue further, correlation between a household's annual expenditure and the amount of remittance was performed. The correlation between household expenditure and the amount a household lends was found to be positive but not significant although in hyacinth infested areas, this relationship was significant (table 4.19). This did not appear to be true for the amount of money a household could borrow, a likely reflection that the household's ability to repay borrowed funds was not the only factor determining assistance received. This finding was true for all households irrespective of their area of residence. Although most of these transactions were reportedly not subject to formal repayment obligations, the positive correlation between the amount remittance and household expenditure was probably because any transaction was preceded by a scrutiny of ones ability to pay and this was so even among kin. The amount of remittance was inversely related to the food share both in hyacinth free and hyacinth infested areas.

The correlation between household annual expenditure and amount borrowed by households was not significant. It could be that, the kin spirit overrides financial considerations following such a crisis.

Table 4: 19 Correlation between amount of remittance and household per capita expenditure

Correlation between	Hyacinth free	Hyacinth infested	Entire sample
Amount 'loaned' and food share	-0.222**	-0.212*	-0.193**
Amount 'loaned' and food share ^a	-0.009	-0.132	-0.052
Amount 'loaned' and food share ^b	-0.284**	-0.275*	-0.244**
Amount 'borrowed' and food share	-0.159*	-0.060	-0.078
Amount 'borrowed' food share ^a	-0.096	-0.303*	-0.217**
Amount 'borrowed' and food share ^b	-0.153	-0.067	-0.069
Amount 'loaned' and expenditure	0.121	0.350**	0.177
Amount 'borrowed' and expenditure	0.121	0.006	0.006
Annual expenditure and food share	-0.340**	-0.329**	-0.307**

Notes: ^a represents fishing households, ^b represents 'non' fishing households. * indicates that correlation is significant at 0.05 level (2 sided) while ** indicates that correlation is significant at 0.01 level (2 sided). Expenditures are on household basis.

Source: Water hyacinth and household welfare survey, 2000/01

4.3 Water hyacinth

Households were asked to give their opinions as to whether from their own experience; the hyacinth had been advantageous, disadvantageous or neutral to their welfare. This close-ended question was to ensure that households had something to say about the hyacinth. The motivation behind this question was the conflicting messages reporting that the hyacinth was disadvantageous while at the same time, others reported the hyacinth to be beneficial.

An overwhelming majority (71 percent) indicated that the hyacinth was disadvantageous while 11 percent indicated neutrality with respect to the hyacinth (table 4.20). Only five percent reported that the hyacinth had been advantageous while a further 13 percent failed to respond to the question. Even in the areas identified as being free from water hyacinth, the response to the question was not any different. It may be that the answers given here were in some part subjective based on what the reports about water hyacinth in the media, which are in most part negative. After all, the study found that most of the household heads had had some formal education and could read a newspaper.

The result confirmed that the hyacinth had detrimental consequences as far as household welfare was concerned. An advantage of this question was that households were able to give their own assessments about the hyacinth.

Such an assessment would then give more credence to the results of the microeconomic assessment of the relationship between household welfare and the water hyacinth outlined in section 4.6. Eighty two percent of households responding to the question i.e. excluding non responses agreed that the hyacinth was disadvantageous.

Table 4: 20 Distribution of the impact of hyacinth on household welfare

Impact	Hyacinth free	Hyacinth infested	Entire sample	Percent of total
<i>Positive</i>	148	103	251	71.2
<i>Neutral</i>	22	15	37	10.5
<i>Negative</i>	10	7	17	5
<i>No response</i>	27	18	45	13.3

Source: Water hyacinth and household welfare survey, 2000/01

Further to this, households were asked to respond to a related question linking their answers about the hyacinth's role in their overall welfare and the areas where this impact was felt. These results are presented on table 4:21 below. The results clearly and unambiguously showed that fishing to most of the heads responding to the question was the most adversely affected endeavour while fetching clean water for domestic use, boat transport health and bathing followed in that order of importance. This appeared consistent with reports from numerous countries among them, Ghana, Papua New Guinea, Kenya, Uganda, Tanzania which indicate that the hyacinth made it difficult for fishermen to operate effectively and efficiently.

For the five percent regarding the hyacinth as good, some of the advantages associated with the hyacinth's presence included the 'emergence' of fish species such as Lungfish (*Kamongo*) and Catfish (*Mumi*). They regarded the hyacinth as providing a 'suitable breeding ground' for these species. The market for these fishes is not as widespread as that of other common species such as Nile perch and Tilapia, but most of the fish was sold locally. They considered this a delicacy, which had been almost extinct for some time, and that larger and more frequent catches were realized after the invasion by hyacinth. This also said that this was particularly so where stationary mats of hyacinth occurred. For instance, it was observed that these species were a common sight in landing beaches such as Sango Rota and Kusa during the period of this survey. Whether this was true for all occasions of hyacinth occurrence was not established by the study. Details showing the quantities of such fish species caught were however unavailable to authenticate the claims of increases in fish catch.

This result partly answered one of the study objectives of whether the water hyacinths' presence induces some economic inefficiency. Although at this stage such a 'conclusion' was not arrived at econometrically (which is left to the latter part of this chapter), it did show that there indeed existed a 'felt' effect from the hyacinths presence.

Table 4: 21 Impact of the hyacinth on different aspects of household welfare

<i>Area of impact</i>	<i>Number of households reporting impact</i>		
	<i>Advantageous</i>	<i>Disadvantageo us</i>	<i>Missing</i>
<i>Fishing</i>	4	155	1
<i>Fetching water</i>	2	119	1
<i>Boat transport</i>	2	121	1
<i>Health</i>	1	123	1
<i>Bathing</i>	2	105	1
<i>Livestock watering</i>	1	98	2
<i>Others</i>	1	3	

Source: Water hyacinth and household welfare survey, 2000/01

Overall, households that felt hyacinth neither had a bad nor good aftermath had a food share of 0.62 while those holding hyacinth with contempt had a food share of 0.66. Those households that viewed hyacinth as advantageous had a food share of 0.71 while those that shied away from the question had a food share of 0.72. On the other hand households that viewed the hyacinth to be disadvantageous had an average monthly adult equivalent expenditure of Ksh 1,949 while those that viewed it as advantageous had an average of Ksh 2,466. Neutral and non-response households had an average expenditure of Ksh 2,706 and 1,967 respectively. The finding here seemed to indicate that those households that stated their being disadvantaged were those with relatively lower adult equivalent expenditures.

With respect to water hyacinth free areas, disadvantaged households reported a food share of 0.68 while advantaged, neutral and non-response households reported a mean food share of 0.68, 0.62 and 0.71 respectively. In hyacinth infested areas, the figures were 0.62, 0.76, 0.63 and 0.74 respectively. Turning to respective per adult equivalent monthly expenditures, disadvantaged, advantaged, neutral and non-response households had the values Ksh 2,159, Ksh 2,607; Ksh 3,490 and Ksh 2,027 respectively in hyacinth free areas. The figures in hyacinth infested areas were Ksh 1,643; Ksh 2,246; Ksh 1,555 and Ksh 1,888 respectively. It therefore appeared that judging from their respective expenditures, those holding hyacinth with esteem were on average better off than those who viewed the hyacinth with contempt. However, judging from their food shares, households claiming to be disadvantaged had a lower food share on average than the advantaged.

For those households that failed to respond to the question, their respective food share and expenditure means appeared to place them in a group with large food shares and low per capita expenditures. Table 4.22 below shows that most households (81 percent) who saw the hyacinth as advantageous were non poor while only slightly over half (55 percent) of those perceiving

the hyacinth to be disadvantageous were non poor. This pattern was true even in the case of hyacinth infested areas.

Table 4: 22 Percentage distribution of households' with perceived hyacinth effect by welfare status

Impact of hyacinth	Welfare group	Hyacinth absent	Hyacinth present	Overall sample
Advantage	hardcore			
	poor	0	16.7	6.3
	overall poor	10	16.7	12.5
Disadvantage	hardcore			
	poor	28.9	34.3	31.1
	overall poor	8.7	20.6	13.5
Neutral	hardcore			
	poor	4.5	40	18.9
	overall poor	0	20	8.1
Missing	hardcore			
	poor	25	61.1	40.5
	overall poor	12.5	5.6	9.5
	non poor	62.5	33.3	50

Notes: Figures are percent of households classified thus

Source: Water hyacinth and household welfare survey, 2000/01

From the above discussion, it is evident of the perceived or 'felt' welfare impact of the hyacinth. The fishes in question, *Kamongo* and *Mumi* are sold locally and their market prices are comparatively lower than the those of Nile Perch or even Tilapia for instance which research has shown have been quickly disappearing from local dinner tables. Given such a scenario, these cheaper fish which may be affordable to the 'poor' may have been the motivation behind the answer that the hyacinth was advantageous. Surprisingly enough, in infested areas, out of all households responding positively to the hyacinth's presence, only one out of seven was a fisherman. Thirty nine percent of all households responding that hyacinth was advantageous were fishermen while 51 percent of those disadvantaged were fishermen.

4.4 Willingness to pay for water hyacinth control

Accompanying the questions about water hyacinth and its perceived impact were questions intended to elicit the willingness to pay for two different water hyacinth control measures—biological control and physical control. Potential answers to these questions were designed to act as indirect estimates of how much the water hyacinth had interfered with household welfare. This was one of the principal tasks of the willingness to pay/accept compensation questions. This alternate method was used to check whether the willingness to pay for hyacinth removal was indeed positive and greater

than zero in which case therefore a negative impact was implied to have existed.

A water hyacinth infestation level card (see appendix III) providing two levels of water hyacinth infestation were presented to the respondent upon which they based their answers. On the first image, the water hyacinth had completely blocked the shore sufficiently to deny access to the lake for boats and/or other lake based activities. The second level on the other hand represented hyacinth infestation levels that were much lighter as it was possible to gain access albeit not without some difficulty. A third image showed (for comparison purposes) a clear shore and water could be drawn without any hindrances and access to the lake by boat without difficulty was possible. All these images were taken from different locations when the hyacinth was at a peak infestation period. As opposed to black and white images, colour images were used, which brought more vitality into the images, as it was possible to identify the hyacinth from other features.

Results (table 4.23) indicated that households were willing to pay non-zero amounts for the control of the hyacinth. This was because as households reported above, hyacinth infestation creates conditions that were injurious to household welfare. Households indicating that hyacinth was disadvantageous were willing to pay larger amounts for biological control as opposed to physical control. They were also found willing to pay larger amounts for control when the hyacinth infestation levels were very high and subsequently lower amounts as the level of infestation receded. In hyacinth infested areas, the amount of money that households were willing to pay was greater than the amount in non-infested areas.

This could be explained by welfare economics; that households in hyacinth infested areas had been pushed further off their original indifference curves, hence the larger willingness to pay values. This argument may be reinforced by the finding that households in hyacinth infested areas had less incomes than their counterparts in hyacinth free areas and therefore would have to devote a large share of their income to control. Even if all households irrespective of area of residence were willing to pay similar amounts for control, then it still follows that households in hyacinth infested areas would have to allocate a larger share of their income-expenditure to control compared to their counterparts in hyacinth free areas.

Curiously, there seemed to be an indication that households were willing to pay more if biological control was used as a control option than they were willing to pay for physical control. It was earlier thought that since biological control was a relatively novel idea at least for these households, then their conception of biological control was that of scepticism if not awe. Whether this trend implies a strong belief in biological control was not clear and can only be explained by further research. There exists a two step process in this decision, the first step being the need to get rid of the hyacinth and secondly, how to get rid of it. Since a lake free of the hyacinth is assumed to be the ultimate objective, and they were willing to pay differential amounts

for control of the hyacinth depending on the chosen control option, then these differential amounts must have been a reflection of differences in control quality. This assumes that there is a separate price for getting rid of the weed common to all control methods on the one hand and a separate price depending on the quality of control on the other. (for more on this, see Mailu *et.al*, 2002)

By the time that the current survey was conducted, the weevils that had been released in the lake had already begun showing signs of succeeding in controlling the weed and thus, infestation levels were much more depressed than those observed before the release of control agents. Though these results may not be sufficient to enable us make hard and fast rules about comparing control methods; they do offer some guide and impetus for further research into the issue. However, what is clear is that, households in hyacinth infested areas may have been forced to operate on lower indifference curves by the hyacinth hence their higher willingness to pay values.

Table 4: 23 Households willingness to pay for hyacinth control by control option

Control option	Infestation level	Hyacinth free	Hyacinth infested
<i>Biological</i>	Level 1	4,301	6,729
<i>Physical</i>	Level 1	2,693	5,832
<i>Biological</i>	Level 2	3,681	3,918
<i>Physical</i>	Level 2	2,349	3,522

Notes: This table shows means of WTP values for households that reported being disadvantaged $\approx 71\%$ of sample and reporting a positive willingness to pay

Source: Water hyacinth and household welfare survey, 2000/01

4.4 Specification Tests: Econometric tests

A scatter graph (figure 4.4) was produced to investigate and anticipate the relationship between income (expenditure) and the food share, which on fitting a linear regression line produced a very low coefficient of determination (R^2) of 0.006. A regression line was fitted through the scatter and as expected, there was a negative association between the food share and the income proxy (expenditure).

Logarithmic transformations were performed on expenditure, physical capital and social capital, a transformation, which can transform non-normal data into normality. All variables (exogenous and endogenous) were then subjected to the Kolmogorov-Smirnov test, which tests for normality in a series of values. From the test, it was concluded that all of these variables were normally distributed and hence satisfied one of the requirements of OLS. This transformation was necessitated by the specification of the Engel curve, which has log expenditure as one of the explanatory variables.

Since OLS was to be used to regress the budget share on a number of variables outlined in the preceding chapter, the model was subjected to

various econometric tests to ensure that other assumptions about the endogenous and exogenous variables as well as the stochastic disturbance term were satisfied. Heteroscedasticity was assumed to have been taken care of by the way the model is stated but it was felt that such arbitrary decisions should not suffice. The Breusch-Pagan test was therefore performed and revealed a statistic which was less than the critical chi square value meaning that heteroscedasticity was not a problem in this particular case.

Auxiliary regressions to test for multicollinearity, which is expected due to the natural interrelationships between economic phenomena, were performed. Some of the variables which showed tendencies of bringing problems of multicollinearity were dropped. The procedure was repeated with the remaining variables and none of these separate regressions indicated an adjusted R^2 greater than 0.9 (suggested as a benchmark and not a strict bound) and it was concluded that though present, collinearity between explanatory variables was not severe. An alternative to the auxiliary regressions—through the use of the condition index revealed that multicollinearity was present but moderate⁴⁹ (Haddad *et al*, 1995).

Normality of the residuals was tested through the Jarque-Bera test which checks whether the skewness (symmetry) and kurtosis (flatness of tails) of the distribution of residuals matches the skewness and kurtosis expected under the hypothesis that the disturbances are normally distributed was applied. It was concluded from this test that the residuals were not normally distributed.

It was initially suspected that there were some influential observations that would alter the slope of the Engel curve. To check whether this suspicion was true, observations were inspected for large leverage. None of the observations had a predicted value greater than the 'calibration point' for hat values (see for example Lovie and Lovie, 1991) that is most commonly used. It was therefore concluded that none of the values had excessive leverage.

The Levi Bounds test for assessing the presence of measurement error on expenditures was performed and both upper and lower bounds derived. The bounds did not reveal a large error of measurement. A missing variable test was performed since an observed false effect of a visible variable may in fact be caused by an unobserved latent variable (Draper and Smith, 1981). The Ramsey Reset test was therefore employed to test for the omission of relevant explanatory variables. A proxy variable matrix Z_r was constructed from the second, third and fourth moments of the fitted values of the dependent variable (food share) after running an OLS on the 'restricted' model. Using an F-test, the coefficients on the columns of the Z_r matrix were not jointly significant when the food share was regressed against all the variables including the proxy variables in matrix Z_r from the 'augmented' model. Residuals were plotted on a scatter plane and a visual examination employed to ascertain whether the model had been correctly identified and

⁴⁹ A condition index in excess of 30 indicates the presence of multicollinearity.

from the examination of the scatter of ε_i against the regressors it was concluded that the model was correctly identified and specified.

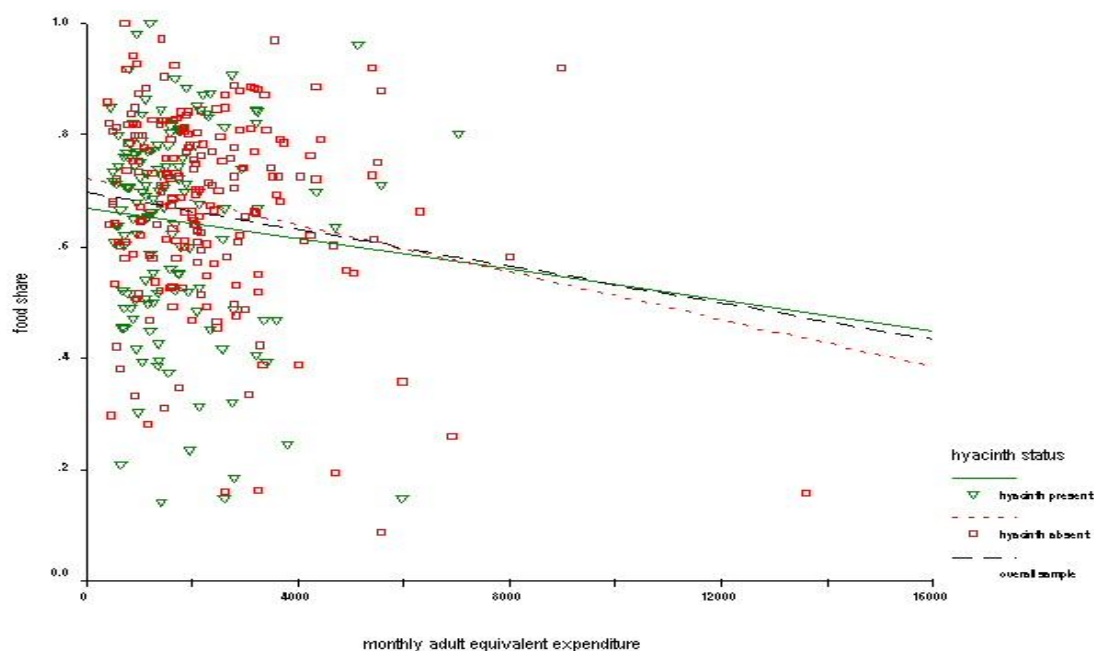


Figure 4: 4 Linear relationship between food share and per capita expenditure

4.5 Ordinary Least Square regression results

Having ensured that the assumptions of OLS were satisfied above, the @SPSS statistical package was used to produce the results shown on table 4:24 through an OLS regression. The Engel curve implied in equation vii in chapter three was used to estimate the relationship between the food share (dependent variable) and the stated explanatory variables. The adding up condition was automatically satisfied by the nature of the specification since the food and non-food budget shares add up to one.

4.5.1 Water hyacinth and the food share

The quality of the physical environment as represented by water hyacinth was found to be associated with low welfare as denoted by larger food shares. The sign of the coefficient was positive indicating that the food share (welfare) increased (decreased) with the presence of water hyacinth. Assuming all other factors zero, households living in water hyacinth infested areas had an intercept that was larger. Although not a practical possibility but a mathematical certainty, when households living in zones free from the hyacinth were estimated to have a food share of zero, (i.e. all expenditure is devoted to non-food items), those in hyacinth infested zones would have a food share larger than that of households in non infested areas by 0.161. This result clearly illustrated that the water hyacinth did have ill welfare effects and it buttressed the results obtained in previous sections. It also bolstered the answer to the first hypothesis leading to the rejection of the

null hypothesis. The result led to the conclusion that the hyacinth did have negative household welfare impacts as the hyacinth draws the food share towards the maximum 1 as shown by the positive coefficient on the water hyacinth dummy.

These results tallied with those of a participatory poverty assessment study, which cited water hyacinth as an environmental condition responsible for poverty. It also confirmed what other numerous studies had shown that the quality of the environment and welfare are intricately related with deteriorating quality acting both as a catalyst as well as a determinant of welfare losses.

4.5.2 Expenditure and the food share

Income—expenditure is a very important determinant of the allocation in the analysis of Engel curves. The income level of the household denoted by its proxy—household expenditure was estimated to have a coefficient, which is negative and significant implying that income, and the food share are negatively related⁵⁰. Because the exact form of non-linear relationships such as that represented by Engel curves is unknown, there is a likelihood of one wrongly concluding either that a relationship exists or that it doesn't exist (Iman and Conover 1978). This, they argue is possible after transformations such as taking logarithms of expenditure have been done and a Pearson correlation coefficient calculated. A Spearman rank correlation coefficient has thus been found more robust and powerful (*ibid*). A Spearman Rank correlation coefficient was therefore calculated and the statistic ($r' = 0.553$) which was statistically significant led to the conclusion that the food share and per capita expenditure were negatively related.

The estimated expenditure coefficient was -0.072 which was significant at 95% suggested that expenditure levels do play a part in determining what fraction is spent on food. The negative sign of the coefficient means that expenditure and the food share move in opposite directions. As the independent variable—expenditure rises, the food share falls and *vice versa*. The stability of the expenditure coefficient across hyacinth infested and uninfested areas implied that the response of the food share in the two areas to expenditure levels is similar.

However on carefully examining the scatter (figure 4.4); it is evident that the slope of a plotted regression line is much steeper for households in hyacinth free areas. This implies that at high income-expenditure levels, households in hyacinth free areas had a lower food share than those in hyacinth infested areas. It is worth noting that a total of 75 percent of the observations fell above the overall expenditure mean of Ksh 1,307 in hyacinth free areas while the respective figure in hyacinth free areas was 55 percent. Plotting a regression line with a quadratic expression, it appears that in hyacinth infested areas, the slope changes from negative to positive as expenditure rises. In these areas therefore, food changes from an inferior good to a

⁵⁰ The Pearson correlation coefficient between income and expenditure was 0.508 and significant at the 0.01 level (two tailed).

necessity and possibly a luxury as income-expenditure increases. In hyacinth free areas on the other hand, food shifts from being luxury to a normal good and eventually into an inferior good as incomes rise along trend. On careful examination of the scatter, the points at which the slopes change direction are close to the mean food share and expenditure values. Why the two slopes would behave this way cannot however be explained.

An auxiliary OLS regression was done on food expenditure per capita as the dependent variable against total expenditure per capita as well as the water hyacinth as a shifter to the intercept as regressors. The intercept in hyacinth infested areas was estimated as 50.4 while for hyacinth free areas it was estimated as 75.2. The slope of the function (expenditure coefficient) was estimated as 0.509 and was positive. A separate regression was done with the inclusion of expenditure and its square implying a quadratic expression of the relationship between household expenditure and food expenditure. From the regression coefficients, the critical values were estimated at Ksh 62 and Ksh 4,892 through use of the quadratic formula. This meant that between these two extreme points, the slope swung from positive to negative. In hyacinth infested areas on the other hand, the extreme points fell between the values of Ksh minus 29,203 and Ksh minus 55, values that were clearly beyond the sample range. In hyacinth free areas on the other hand, the critical values fell at Ksh 65 and Ksh 4,685.

The economic implication of these results is that at the two sets of extreme points, expenditure on food is zero. This is mathematically certain but practically impossible implying that the actual values lie somewhere between these extremes. Its impossibility arises due to the fact that human beings must eat to live, hence, zero food consumption is not an option. Also implied by these extreme points was that even when expenditure is zero, food expenditure is not zero. Besides, the observed minimum per capita expenditure in the dataset was Ksh 97 while the observed minimum per capita food expenditure was Ksh 34. The maximum values in the dataset were Ksh 3,402 and Ksh 2,059 for total expenditure and food expenditure respectively; all registered in hyacinth free areas. These when imputed into the estimated regression translated into minimum food expenditures of Ksh 29 in hyacinth free areas and Ksh 95 in hyacinth infested areas. The maximum food expenditure was therefore estimated as Ksh 3,043 and Ksh 991 in hyacinth free and hyacinth infested areas respectively. For the entire sample, the estimated minimum food expenditure was Ksh 31 while the maximum was Ksh 2,863 all values being non zero and outside the range implied by negative magnitudes in the regression coefficients. Whether this food was acquired in cash or otherwise did not change the food share in any appreciable way.

The seemingly divergent conclusion could now be explained by the fact that most of the observations of the food share lie within the margins set by the coefficients. This result appears to be in line (although not entirely) with

Deaton's (1997) remark that making people well off in poor areas such as sub Saharan Africa will make them consume more food not less.

The estimated regression coefficients yielded food share expenditure elasticities, which were consistent with economic theory⁵¹. Households in hyacinth infested areas had a food share elasticity of 1.15 while the elasticity in hyacinth free areas was estimated as 1.37.

4.6.3 Main occupation of household head and the food share

The sign of the coefficient on main occupation of the household head showed a positive relationship with the food share indicating that households whose head were fishermen had (lower) larger (welfare) food share. However, from the regression, the occupation of the household head did not show any significant association with the food share and was subsequently dropped from the estimation. The inclusion of this variable also made results of the regression to be unstable hence the decision to exclude it from the estimation. As a replacement, a (0,1) dummy 1 for households that had earned fishing income during the past one year and zero for households that did not earn any income from fishing was chosen. The coefficient was also not statistically significant and this variable behaved just like the earlier one hence, it was also dropped from the estimation. Although fish consumption in hyacinth infested areas was lower, the food share in general did not change according to whether or not the household was a 'fishing household' or not. It could have been that for such households, another food type might have been used to replace fish in the household diet. This may mean calorific changes and subsequently nutritional changes that may or may not have adverse impacts.

Due to the correlation between the age of household head and experience at current occupation, the former was dropped from the estimation in favour of the latter. Years of experience at current occupation had a coefficient with a negative sign implying that experience at an activity may increase the efficiency of households probably increasing its income earning ability. In addition, this coefficient was statistically significant ($t=3.17$). Assuming that older households are headed by heads with longer periods of experience in a certain trade, this result also implies that younger households have a generally lower welfare status. According to the lifecycle hypothesis, the earlier years are years of budget deficits and this could probably be what is being depicted here since younger families may have to spend larger portions of their income on some items such as education and clothing for children.

The number of different occupations that household members were engaged in was found to be positively related to the food share. Many different occupations most likely characterize a form of insecurity since household members here are trying to minimize perceived risks that are inherent in the reliance on one income source. The result therefore simply shows that rather

⁵¹ These elasticities are calculated by dividing the marginal budget share by the average budget share all calculated at sub-sample means.

than determining the food share, the number of different occupations is a measure of the risk or uncertainty faced by a particular household in respect to the security of its income sources.

4.6.4 Household size and the food share

Household size, represented in adult equivalents was negatively related to the budget share indicating that large households devote a smaller proportion of their budget on food. Since younger households are most probably of relatively smaller sizes, it appears that just like the above result, such households spend larger fractions on food. From an earlier study, it was concluded that a large household is one of the characteristics of poverty (Greer and Thorbecke, 1986). This means that large households have a higher probability of being poor. However, a different study indicated that this is did not apply for all household sizes. In that study, the food share first increased with household size and then reached a peak after which it began declining (Opondo, 1988).

Large households appear to spend less than smaller households do. Smaller households, which are most likely young, are in the earlier stages of their income cycle. They are characterised by less income (from the life cycle hypothesis), which is subsequently devoted to many of the expenditures consistent with such young households such as pre-schooler care. Large households are found to devote successively smaller proportions of their expenditure on food than smaller households do. An intuitive explanation for the sign of the regression coefficient can be derived from the assertion that large households are better positioned to capitalise on economies of size unlike relatively smaller households. The coefficient on household size was also statistically significant.

Supplementary results also showed that the proportion of dependants is directly related to the food share. This served as an indication that households with many dependants are in most part constrained and hence, may not have enough income left for other commitments.

4.6.5 Gender of household head and the food share

Surprisingly, gender of the household head was not found to be a significant factor in determining the welfare status of a given household. The estimated coefficient though not statistically significant was positive showing that female headed households may devote a larger share of their expenditure to food. The mean food share for female headed households in the overall sample was 65 percent while for male headed households, it was slightly larger at 67 percent. It had been expected that women heads are more predisposed to spend more of their income on food than males, notably because they have fewer resources at their disposal and because food is customarily a 'female' responsibility. However, such a result concurs well with earlier results of the WMS which found that gender differences in the rural areas do not translate in differences in poverty levels (Republic of

Kenya 2000). In this study, poverty levels are closely related to how well a household is able to satisfy its needs—especially nutritional ones. This result was probably a reflection of the fact that hyacinth had interfered with fishing, a predominantly male activity. This may have undermined income generation from the industry, which is then reflected by a devotion of larger shares on food by affected households. The data revealed that households whose heads had fishing as the main economic activity devoted a larger share of their budget (0.66) to food as opposed to 0.62 by households whose heads were engaged in economic activities other than fishing. This variable was however deleted from the final estimation since it also rendered the regression unstable.

4.6.6 Infrastructure and the food share

Accessibility or the level of infrastructural development also has a negative relationship with the food share indicating that access to various facilities and services e.g. markets for fish improves the households ability to earn more income. The coefficient was statistically significantly different from zero but was dropped from the final estimation due to multicollinearity. Infrastructural development is a prerequisite for welfare improvements to occur especially since the major export commodity from the area—fish is highly perishable and cannot get to better markets without an adequate (both qualitatively and quantitatively) road network.

4.6.7 Social capital and the food share

As expected, capital available to the household is found to be a very important ingredient in the welfare standards of the households studied. Physical capital, human capital and social capital all had the expected negative signs. These signs indicate that the food share decreases as the level of capital increases. Although the number of cross transactions between one household and the rest in a village may not be the most ideal candidate as a measure of social capital, it was found sufficient for our purposes. Social capital had a negative and significant coefficient (-0.027) indicating that if households increased their level of interaction, (welfare) the food share would (increase) decrease. Social capital can improve on the ability of human co-operation as can be deduced from plate 4.3 which shows an example of the outcome of community co-operative action. The construction of the passage was necessitated by the inability of fishermen to access the fishing grounds. Due to their predicament, they came together to construct the structure which allows some fishing even during times of hyacinth invasion. This is one of the advantages and therefore, strengths of social capital since it improves on the range of human adaptations. It may also act as a catalyst by ensuring interaction whose outcome is co-operative action towards a common external threat such as water hyacinth.

4.6.8 Household human wealth and the food share

Human capital accumulation, measured by years of experience the household head has at the current occupation would lead to an improvement in household welfare. This coefficient implies that households whose heads have more years of experience have lower food shares. This may be due to the

notion that experience is an ingredient of efficiency, while efficiency on the other hand improves income earning capacity. This is only one aspect of human capital accumulation—measured by years of experience. Households whose heads are relatively more educated (with at least secondary school education) have a smaller food share than those households whose heads have not received at least some secondary school education. This result is in line with Shultz's education hypothesis, which implies that educated people are better favoured by technical changes and adapt better and faster to these changes. This is the other dimension of human capital used in this study. This result too corresponds to the results of the 1997 WMSIII which show that education is an additional ingredient in ensuring improvements in living standards.

4.6.9 Household physical capital and the food share

Physical capital however was not found to be a significant determinant of household welfare at the 10% level although the coefficient had the expected sign. The inverse relationship between physical capital and the food share implies that physical capital improves the earning ability of households which in turn, through the workings of Engel's law leads to proportionately less expenditures on food. Why the coefficient was not significant is not quite clear but it is possible that the time between infestation and the timing of this study was not sufficient to notice appreciable changes in asset ownership since the accumulation of these is also dependent on time. However, this variable led to multicollinearity and was subsequently dropped from the final estimation.

4.6.10 Poverty and the food share

Poor households living in hyacinth infested areas were estimated to have smaller food shares than their counterparts (difference of 0.176) in hyacinth free areas. This result meant that the Engel curve slopes downwards from left to right if one substitutes these results on a coordinate system. It also meant that poor households in hyacinth free areas are more constrained since their food share is effectively larger than those living in hyacinth infested areas, this effectively providing an answer to the question implied by the second hypothesis.

Table 4: 24 Ordinary Least Squares regression coefficients

Variable	Coefficient	Standard error	T statistic	Sig	Mean	Std. Dev
Intercept	1.32	0.24	5.496	0.00		
Residing in busia? (yes=1; else=0)	-0.0542	0.031	-1.721	0.086	0.3543	0.479
Residing in Nyando? (yes=1; else=0)	-0.0323	0.04	-0.797	0.426	0.2371	0.4259
Residing in Migori? (yes=1; else=0)	0.0626	0.027	2.309	0.022	0.22	0.4148
Residing in hyacinth infested area? (yes=1; else=0)	0.2080	0.086	2.421	0.016	0.4086	0.4923
Household head received secondary education? (yes=1;else=0)	-0.0691	0.02	-3.499	0.001	0.2727	0.4402
Household head's experience in current occupation (years)	-0.0023	0.001	-3.171	0.002	15.126	11.8328
Log adult equivalent household size	-0.0967	0.028	-3.406	0.001	1.2807	0.5147
Inverse monthly expenditure per adult equivalent	96.298	105.049	0.917	0.36	0.0002	0.000017
Log adult equivalent monthly expenditure (ksh)	0.0720	0.026	-2.771	0.006	7.434	0.6234
Interaction between variable 5 and variable 10	-0.0177	0.013	-1.352	0.177	2.307	2.8551
No. of different occupations household members are engaged in	0.0333	0.0012	2.864	0.004	1.7471	0.8043
Log of No. of cash & noncash transactions household entered into	-0.0272	0.014	-1.996	0.047	0.6197	0.617
Subsistence orientation (%)	0.0002	0.0001	0.945	0.345	42.376	34.4952
Household defined as poor and living in hyacinth infested area	-0.1760	0.031	-5.68	0.001	0.2686	0.4439

Notes: Coefficient of determination (R^2) = 0.315; Adjusted (R^2)=0.286; $F=11.009$; $N=350$

Source: Water hyacinth and household welfare survey, 2000/01

CHAPTER FIVE

5.1 Conclusion

It is evident from the results presented in the preceding chapter that water hyacinth does play a major role in determining the allocation of expenditure to food by households. The results indicate that the water hyacinth is injurious to household welfare although this injury is not more significant for poor households. This evidence then helps summarise the need for the ongoing water hyacinth control campaign, control that should be guided by the principle of efficiency. The evidence points an accusing finger on the hyacinth as a cause of diseconomies and therefore, such diseconomies could be reduced or eliminated by water hyacinth control the former being the more realistic of the two options. A redistributive policy is advocated where public expenditure is directed to affected households. For instance, the micro projects being funded through the LVEMP could have this sort of bias with a lot of care being taken to avoid free riders. The principle of equity is invoked on this account especially now when the Kenya Government has embarked on its poverty reduction plan. Strategies that improve household incomes would go a long way in mitigating the adverse effects of the hyacinth on household welfare.

Generally, a larger proportion of households in hyacinth infested areas could not adequately meet needs, especially food needs, a sure ingredient of low self esteem. The fact that households feel that their well being is mediocre is important to have in mind since their self esteem—a very fragile emotion—can easily be compromised. A situation where people have low self esteem might not be relied upon to produce the necessary urging to stir people away from poverty. In essence, aspects such as education, which have a long gestation before they bear fruit are very important since the consequences of illiteracy may be difficult to eradicate. As education in Kenya becomes more and more inaccessible, at least for those without a sound financial background, the ramifications of this fact are a grim future for affected households.

Education may as well be used both as a short and long-term measure to ensure that households become more amenable to changes emerging in the lake since technically, the hyacinth will remain in the lake at least into the foreseeable future. Education can act in a dual manner, on the one hand, enabling households to understand the weed as a potential resource and on the other hand, enable them adapt better to the changing fortunes. Education becomes more crucial since biological control is a relatively alien concept which may require the help of lakeshore residents in implementing and monitoring progress of control and thus, education becomes a plus in this endeavour. It may not be too ambitious to expect that well educated persons understand not only the welfare implications of such noxious weeds but also the legal implications of handling them.

The history of many successful economies indicates that they were successful because they were civil and not the other way round. Communal

management regimes in natural resource management has also been in the forefront in ensuring the sustainability of natural resource use. Social capital has been pointed out as the glue that kept together the leaves of natural resource management. Social capital is definitely capital and is surely social but is something whose growth may not lie directly within the purview of the state but can however be encouraged through more general government policy. However, the most appropriate policy tools that are implied cannot be pinpointed until more research is carried out to unveil the exact route through which policy prescriptions can address social capital and its growth as well as its maintenance. The role of credit cannot be overemphasised as results from this survey show a reliance on informal credit as a means to cope with income-consumption incongruity. The provision of credit should be enhanced and as much as possible, this provision should borrow a leaf from the informal rules that ensure the smooth functioning of informal credit. This is because moral hazard and incentive problems are much more clearly dealt with within informal associations rather than on the formal rules characterising formal credit provision, which has performed dismally in the past.

The water hyacinth appears to strengthen kinship ties. This is probably because this kind of behaviour enhances overall productivity or even more important, minimizes the decline in productivity. In this case, people help each other overcome the setbacks occasioned by the water hyacinth. On the whole, such desirable social relationships may have positive externalities. However, since no individual cannot appropriate these externalities (social capital has characteristics of a public good), then agents may tend to underinvest in social capital and thus, it naturally calls for some role for public support.

Infrastructural developments should also be among priority areas of the government expenditure regime as the results indicate that infrastructural development is an important ingredient in welfare determination. Road maintenance is an expensive undertaking and therefore, all stakeholders should be through a predetermined means encouraged to take part in maintenance. The road network in some of the tea estates of Kenya's main tea growing districts should serve as a good example while drawing on its successes and at the same time learning from its weaknesses. This would go a long way in improving the efficiency of artisanal fishing as the presence of water hyacinth produces diseconomies such as possible drops in catch per unit effort or even fish spoilage.

Results indicate that biological control has a strong backing from resident communities in the lake. In other words, the result in an indirect way validates the choice to use biological control as a first line defence against water hyacinth, and presumably, other waterweeds. In future therefore, policy in making fast responses to such attacks should take cue from this result and consider biological means of controlling waterweeds almost as automatic. Households in hyacinth infested areas are found to be willing to pay larger amounts of money for control even when results indicate that

their incomes are much lower. This means that they are willing to devote a larger share of their income in hyacinth control than those who are not affected by the hyacinth are. This result also seems plausible in the case of agricultural pests and weeds and therefore, the wide application of this finding may suffice.

The bottom line is that, the water hyacinths proliferation should be seen as a symptom of the basic underlying forces of which point and non point pollution are some of the most visible. Pollution prevention and/or minimisation should be a priority in the many issues regarding the state of the lake's environment and the welfare implications that its health entails. The introduction of such weeds into new environments should not only be legislated upon but policed too.

5.2 Recommendations for Research and Policy

This study does not provide all the necessary answers for making policy recommendations. Although this research shows the hyacinth in negative light, it is recommended that further research is conducted to shed light into intrahousehold reorganisation—if and how it occurs in the light of hyacinth invasion. It could be that such reorganisation hurts a group of people in the household more than it does others as suggested by Haddad, Hoddinott and Alderman (1997). However, one emerging shortcoming in this study was that the nutritional content of measured food expenditures was unmeasured. Specifically, a nutritional study could bolster the results of this work so as a complete picture of household food consumption may appear.

The fact that households reveal greater willingness to pay values for biological water hyacinth control as opposed to physical control should be explored further. This is because, although an integrated hyacinth control approach is envisioned, the finding should prompt water hyacinth control authorities to find out why this is so since they are heavily dependent on the attitudes of the community in providing logistical help in hyacinth control initiatives. Results from the contingent valuation technique validate the finding that water hyacinth is indeed a cause of low welfare and that households are willing to pay positive amounts for control. Whether this willingness can be transformed into actual payments is anybody's guess and can be answered from further research. The place of integrated control in this scheme should be investigated with a view to providing a more comprehensive coverage of the same issues. For instance, is integrated hyacinth control more acceptable than either of its components or are there some components of integrated control that may receive more support? This result also prompts one to ask whether biological control attracts the same kind of response when the pest is not just a waterweed but an agricultural pest as well. Further research could be applied in line with the finding of this study to unearth attitudes towards control options especially as regards agricultural weeds as well as insect pests. These are factors that reportedly cause huge losses especially for farmers who cannot readily access and/or

afford commercially available chemical control options such as herbicides and pesticides.

In a different light, it should be considered that other uses of the hyacinth be explored as has happened in other countries such as Bangladesh where the hyacinth has been used for productive purposes on a small scale. Such could help alleviate albeit in a small way the problem of unemployment in the country. Since technologies such as those applicable in waste water treatment are currently in use, local authorities may look into the possibilities of adopting these for such secondary sewage treatment plants which are twice as cheap to build and four times as cheap to operate as advanced plants. Such an adoption would be a major milestone in ridding Lake Victoria of pollution from untreated effluent as many of the treatment facilities in the lakeside towns are either overwhelmed by sewage or are simply non functional. However, this also calls for an understanding of these uses and their constituent benefits vis-à-vis the findings and conditions of this study that the hyacinths presence is injurious to household welfare. This in other words means that a cost-benefit analysis should precede any decision to adopt a 'hyacinth friendly' stance with respect to its potential benefits.

It is also recommended that if this study findings can be generalised for the entire population residing next to Lake Victoria, then the three countries should adopt some of the recommendations in order to harmonise policy. This could go a long way in determining common and appropriate policy recommendations across the three East African neighbours.

REFERENCES

- Abila R.O. (1998) Socio-economic Impacts of Trawling in Lake Victoria. **In:** *Trawling in L. Victoria: Its History, Status and Effects* J.S. Mbuga et al. (eds.) Socioeconomics of the Lake Victoria Fisheries, Report number 3, IUCN, Eastern Africa Programme, August, 1998.
- Achieng, A.P. (1990) The Impact of the Introduction of Nile perch *Lates niloticus* (L.) on the fishermen on Lake Victoria. *In: Journal of Fish Biology* (supplement A): 17-23
- Afullo O.A.T (1995) "Pollution of Lake Victoria by Inorganic Fertilizers used in the West Kano Rice Irrigation Scheme". Unpublished Mphil thesis, Moi University, Eldoret.
- Ahmed R. and Mahabub H. (1990) *Developmental Impact of Rural Infrastructure in Bangladesh*. IFPRI research report 83. IFPRI, Washington D.C.
- Ainsworth M. and van der Gaag J. (1988): *Guidelines for Adapting the LSMS Living standards questionnaire to local conditions* LSMS Working paper No. 34, The World Bank, Washington D.C.
- Alderman, H. (1990) *Nutritional Status in Ghana and its Determinants: Social Dimensions of Adjustment in sub-Saharan Africa*: Working paper no 3 edited by Michel Noël, SDA Unit, The World Bank, Washington D.C.
- Alderman, H. and Garcia, M. (1993) Poverty, Household Food Security and Nutrition in Rural Pakistan, IFPRI research report Number 96, IFPRI, Washington D.C.
- Anon (1996b) Control of water hyacinth and other invasive weeds in lake Victoria a draft research project proposal, Kenya Agricultural Research Institute, Nairobi.
- Anon, (1996) Lake Victoria Environmental Management Programme, Proposal, Final Report to the World Bank, Arusha, Tanzania. 323pp.
- Anzagi, S. and Bernard, F.E. (1977) Population Pressure in Kenya: A Preliminary Report, Central Bureau of Statistics Government printer, Nairobi.
- Argyle, M. (1991) *Cooperation: The Basis of Sociability*, Routledge, London.
- Aston, H.I. (1973) *Aquatic Plants of Australia*, Melbourne University press 1973, 366 pp
- Ayot O. H. (1977) *Historical Texts of the Lake Region of East Africa*, Kenya Literature Bureau, Nairobi.
- Bakar B.B.; Amin S.M and Yusof E.B. (1984) Water Hyacinth *Eichhornia crassipes* (Mart.) Solms in Malaysia: Status of Distribution, Problems and Control in Thyagarajan G. (ed) Proceedings of the International Conference on Water hyacinth, Hyderabad, India, February 7-11 1983, UNEP, Nairobi.
- Balterbury, S. and Forsyth, T. (1999) Fighting Back: Human Adaptations: In Marginal Environments. *Environment* 41 (6): 6-11
- Barel C.D.N.; Ligtoert W.; Goldschmidt T.; Witte F. and Goundswaard P.C. (1991) The haplochromine cichlids in Lake Victoria: An Assessment of Biological and Fisheries Interest *In: Cichlid Fishes, Behaviour, ecology and evolution* pp 258-79, Chapman and Hall, London.

- Barten A.P. (1987) In: *The New Palgrave: A Dictionary of Economics* edited by J. Eatwell, M. Milgate and P. Newman, Vol 2 pp??-??, The Macmillan Company, New York.
- Batanouny, K.H. and El Fiky, A.M. (1984) Water Hyacinth in Egypt. In: *Proceedings of the International Conference on Water Hyacinth*. Thyagarajan, G (ed) pp 127-144, UNEP, Nairobi.
- Baumol, J.W. (1977) *Economic Theory and Operations Analysis*, fourth edition, prentice-Hall , inc., Englewood Cliffs, New Jersey
- Bebawi, F.F. (1972) Studies on the Ecology of *Eichhornia crassipes* (Mart) Solms. in The Sudan. Unpublished MSc Thesis, University of Khartoum.
- Begon M., Harper L.J. and Townsend, R.C. (1990) *Ecology: Individuals, Populations and Communities* 2nd edition Blackwell Scientific Publishers, Boston.
- Benjamin, D. and Deaton, A. (1993) Household Welfare and the Pricing of Cocoa and Coffee in Cote d'Ivoire: Lessons from the Living Standards Surveys. In: *The World Bank Economic Review*, Volume 7 Number 3, 1993, pp293-318
- Blau, P.M. (1964) *Exchange and Power in Social Life* John Wiley and Sons, inc, New York
- Boadway, R and Bruce, N. (1984) *Welfare Economics*, Blackwell publishers, Oxford U.K.
- Boes, M. (ed) (1992) *Encyclopaedia of Laws*, Volume 1: Environmental Law, Kulwer Law and Taxation Publishers, Deventer, The Netherlands
- Bokera C. and Ikiara, M. (2000) The Macroeconomy of the Export Fishing Industry in Lake Victoria (Kenya) IUCN Eastern Africa Programme, Socio-economics of the Lake Victoria Fisheries, (Report number 7), April, 2000, Nairobi
- Bos R. (1997) The Human Health Impact of Aquatic Weeds *proceedings of the International Water Hyacinth Consortium*: Delfosse E.S. and Spencer N.R (eds.), World Bank, Washington D.C 18-19 March, 1997.
- Bouis H.E. and Haddad L.J (1990) *Effects of Agricultural Commercialisation on Land Tenure, Household Resource Allocation, and Nutrition in the Philippines*. IFPRI Research Report No 79, IFPRI, Washington D.C.
- Branson H.W. (1992) *Macroeconomic Theory and Policy* Second edition Universal Book Stall, New Delhi.
- Bright, C (1998) *Life out of Bounds: Bioinvasion in a Borderless World* W.W. Norton and Company, New York.
- Bugaari, H.; McNabb, T.J and Moorhouse, T.G. (1998) The Water Hyacinth Problem in Lake Victoria, WP-010298, East Africa, Aquatics Unlimited, Kampala, February, 1998, Uganda
- Bugenyi, F.W.B. (1982) The Aquatic Environment and Pollution in Uganda— Current Status and Conservation Measures. In: Okidi, Charles O. and Olindo, P.M. (eds.) *Quality of water and its impact on the living resources of the Lake Victoria basin*. A workshop report, Kisumu pp88-109.
- Carvalho S. and White, H. (1997) *Combining the Quantitative and Qualitative Approaches to Poverty Measurement and Analysis: The Practice and Potential*; World Bank Technical Paper No 366, The World Bank, Washington D.C.

- Celis, R and N. Bliven (1991) Household Expenditure Behaviour and Household Revenue Determinants. In: Celis, R. J.T. Milimo and S. Wanmali (eds.) *Adopting Improved Farm technology: A Study of Smallholder Farmers in Eastern Province, Zambia*, Occurrence paper, IFPRI, Washington D.C.
- Center T.D., Dray F.A. jr., Jubinsky G.P and Leslie A.J. (1999) Water hyacinth Weevils (*Neochetina eichhorniae* and *N. Bruchi*) Inhibit Waterhyacinth (*Eichhornia crassipes*) Colony Development *Biological control* 15, pp39-50 Online at <http://www.idealibrary.com>
- Chambers R. (1983) *Rural Development: Putting the Last First*, John Wiley and Sons, New York.
- Chikwenhere G.P (1994) *Biological Control of water Hyacinth (Eichhornia crassipes) in Zimbabwe: Results of a pilot study*; FAO Plant Protection Bulletin, 42: 185-190.
- Chikwenhere G.P and Keswani (1997) Economics of Biological Control of Kariba Weed (*Salvinia molesta*) at Tengwe in North Western Zimbabwe: A case study, In: *International Journal of Pest Management* Vol 43 no 2, April-June 1997, edited by Kidd N.A.C and Jervis M.A. Taylor and Francis Publishers.
- Chikwenhere G.P. and Phiri G. (1999). History of Water Hyacinth and its control efforts on Lake Chivero in Zimbabwe, **In:** Hill M.P., M.H. Julien and T.D. Center (Eds.) *Proceedings of the First IOBC Global Working Group Meeting for the Biological Control and integrated control of Water Hyacinth*, 16-19 Nov 1998, St. Lucia Park Hotel, Harare, Zimbabwe, pp 91-105
- Cleaver, K.M and Schreiber, G.A. (1994) *Reversing the Spiral: The Population, agriculture and environment nexus in Sub Sahara Africa*, World Bank, Washington D.C. 293pp.
- Cofrancesco, A.F. Jr.; Stewart, R.M and Sanders, D.R. Sr. (1985) 'The Impact of *Neochetina eichhorniae* (Coleoptera: Curculionidae) on water hyacinth in Louisiana'. *Proceedings of the VIth International Symposium on Biological Control of Weeds*, pp 525-535.
- Corbett, J.D., S.N. Collis, B.R. Bush, E.I. Muchugu, R.Q. Jeske, R.A. Burton, R.E Martinez, J.W. White and D.P. Hodson (1999) *Almanac Characterisation Tool: A Resource Base for Characterising Agricultural, Natural and Human Environments*. Texas Agricultural Experiment Station, Texas A&M University System, Blackland Research centre Report 99-06, (ver. 2.0.3) CD ROM.
- Crul R.C.M; Silvestre, G.T; Postman, D.J; Ojiem, M.J.P; Acere, T.O. and Bougers, G (1993) Monographs of the Great African Lakes. Limnology and Hydrology of Lake Victoria pp 1-81 Bibliography of Lake Victoria (East Africa). International Agriculture Centre, Wageningen, The Netherlands.
- CSIRO (1998) *Weevils Wipe out Killer weeds in PNG* Available Online at: <http://www.csiro.org/page.asp?type=featureArticle&id=WaterHyacinth>
- Dasgupta, P. (1995) Poverty, Population and the Environment **In:** *Property Rights and the Environment: Social and Ecological Issues*, Susan Hanna and Mohan Munasinghe (eds.), The Beijer International Institute of Ecological Economics and the World Bank. pp141-162.

- Deaton A. (1989) Savings in Developing Countries: Theory and Review" in *Proceedings of the World Bank Annual Conference on Development Economics*, ed. S. Fischer and D. de Tray, World Bank, Washington D.C.
- Deaton A. (1997) *The Analysis of Household Surveys: A Microeconomic Approach to Development Policy*, The John Hopkins University Press, Baltimore.
- Deaton A. and Muellbauer, J (1980) *Economics and Consumer Behaviour* Cambridge: Cambridge University Press.
- Delgado, C.L., Hopkins J., Kelly, V.A, P. Hazell, A.A. McKenna, P. Gruhn, B. Hojjati, J. Sil and C. Courbois (1998) *Agricultural Growth Linkages in Sub-Saharan Africa* Research Report 107, IFPRI, Washington D.C.
- DN Daily Nation Various issues.
- Draper N.R and H. Smith (1981) *Applied Regression Analysis*, Second edition, John Wiley and Sons, New York.
- Dwivedi D.N. (1991) *Principles of Economics*, Vikas Publishing House PVT, New Delhi.
- ENN (1997) Lake Victoria Ecosystem Threatened by Pollution, Weeds, ENN feature article by G. Owuor available online at : http://www.enn.com/news/enn_stories/1997/03/032497/feature.asp
- ENN (2000) Tiny Fly Recruited for Herculean Task, ENN News available online at: http://www.enn.com/news/enn_stories/2000/03/03052000/hyacinth_10708.asp
- EPA (1989) Water Quality for the Nation's Lakes: Report to Congress, Environment Protection Agency of the United States, Washington D.C
- FAO (1998) Integrated Control of Aquatic Weeds: Project Findings and Recommendations—Ghana: Terminal Report. AG:GCP/GHA/026/EEC. Online at: <http://www.fao.org/docrep/field/381333.htm>.
- FAO (2000) Fighting water weeds in West Africa, News and Highlights. Online at: <http://www.fao.org/news/2000/000705-e.htm>
- Ferroni M. and Kanbur R. (1990) *Poverty Conscious Restructuring of Public Expenditure*, SDA working paper no. 9. Policy analysis, World Bank, Washington D.C.
- Folkertsma, C. (1996) *On Equivalence Scales*: Tinbergen Institute Research Thesis.
- Freeman III, M.A. (1993) *The Measurement of Environmental and Resource Values: Theory and Methods*, Resources for the Future, Washington D.C. 516pp
- Gangstad E.O and Cardarelli, N.F. (1990) The Relation Between Aquatic Weeds and Public Health **In**: *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation* A.H. Pieterse and K.J. Murphy (eds.) 1990; Oxford Science Publishers, New York. pp85-90
- Geheb K. and Tony B. (1997) Fishing Farmers or Farming Fishermen? The Quest for Household Income and Nutritional Security on the Kenyan Shores of Lake Victoria *African Affairs*(1997), 96, 73-93
- Geheb, K. (1997) The Regulators and the Regulated: Fisheries Management, Options and dynamics in Kenya's Lake Victoria Fishery. Unpublished D.Phil. Thesis, University of Sussex, Falmer, Brighton, U.K. Reprinted as LVFRP Technical Document No 10. LVFRP/TECH/00/10. The Socio-

- economic Data Working Group of the Lake Victoria Fisheries Research Project, Jinja.
- Geheb, K. (ed) (2000) The Co-management Survey: PRA reports from five beaches on Lake Victoria. *LVFRP Technical Document No. 9 LVFRP/TECH/00/09*. The Socio-economic Data Working Group of the Lake Victoria Fisheries Research Project, Jinja.
- Githinji, M. wa. (1995) "Time Allocation and Gender in Kenya" Background paper for the Human Development Report 1995, published for UNDP by the Oxford University Press, New York.
- Glewwe P. (1990) *Investigating The Determinants of Household Welfare in Côte d'Ivoire*, LSMS working paper No 71 World Bank, Washington D.C.
- Gopal B. (1987) *Water Hyacinth: Aquatic Plant Studies*, Elsevier Science Publishers B.V., Amsterdam. 471 pp.
- Greathead, A. and de Groot, P (eds.) (1993). Control of Africa's Floating Water Weeds. Proceedings of a workshop held in Zimbabwe, June 1991. Commonwealth Science Council, CAB International and Biomass Users Network, CSC Agriculture Program Series Number CSC(93)AGR-18, Proceedings 295, 186 pp.
- Gréboval, D (1989) Management of the New Fisheries of Lake Victoria: major Socio-economic issues, UNDP/FAO Regional Project for Inland fisheries Planning (IFIP). RAF/87/099/TD/04/89 (En)
- Greer J. and Thorbecke E. (1986) Food Poverty and Consumption Patterns in Kenya, ILO, Geneva, Switzerland.
- Grosh, M. and Glewwe P. (1995) *A Guide to Living Standards Measurement Surveys and their Data Sets*; LSMS Working Paper No 120, World Bank, Washington D.C.
- Haddad, L., Hoddinott, J., and Alderman, H. (1997) *Intrahousehold Resource Allocation in Developing Countries: Models, Methods and Policies* The John Hopkins University Press, Baltimore for IFPRI, Washington D.C.
- Haddad, L; Westbrook M.D.; Driscoll, D.; Payongayong, E.; Rozen, J.; and Weeks, M. (1995) *Strengthening Policy Analysis: Econometric Tests Using Microcomputer Software*. Microcomputer in Policy research 2, IFPRI, Washington D.C.
- Hamdoun A.M. and Tigani K.B. (1977) Weed Problems in the Sudan, PAN 23: 190-194.
- Hardwick P., Khan B. and Langmead J. (1994) *An Introduction to Modern Economics* 4th edition ELBS and Longman publishers
- Harley K.L.S (1994) *Eichhornia crassipes* (Mart) Solms-Laubach. Weed Management for Developing Countries. In: P. Labrada, J.C. Caseley and C. Parker (eds.). Pp 123-124. FAO Plant Production and Protection Paper No 120, Rome, FAO. 284pp.
- Harley K.L.S., Julien M.H., and Wright A.D. (1996) *Water Hyacinth: A Tropical Worldwide Problem and Methods for its Control*; International Weed Control Congress, Copenhagen, 1996
- Hassan M. R. (1979): Dangers and Utilization of the Water Hyacinth In: *Plant Research and Development* vol 10: A Biennial Collection of recent German Contributions concerning development through plant research: Institute for scientific Corporation, Laupp & Göbel, Tübingen.

- Hazell, P.B.R., and A. Röell (1983) *Rural Growth Linkages: Household Expenditure Patterns in Malaysia and Nigeria*. Research Report 41. International Food Policy Research Institute, Washington D.C.
- Hecky R.E (1993) The Eutrophication of Lake Victoria. *Verh. Int. Ver. Limnol.* 25, 39-48
- Hentschel, J. and Lanjouw, P. (1996) *Constructing an Indicator of Consumption for the Analysis of Poverty: Principles and Illustrations with reference to Ecuador*. LSMS paper no 124, World Bank, Washington D.C.
- Herdendorf, C.E (1990) Distribution of the World's Large Lakes. In: Tilzer M.M. and Serruya C. (eds.) (1990) *Large Lakes: Ecological Structure and Function*, Brock/Springer series in contemporary bioscience, Springer-Verlag, Berlin. pp 3-38
- Heyer, J; Maitha J.K and Senga, W.M (eds.) (1976) *Agricultural Development in Kenya: An Economic Assessment*, OUP, Nairobi, 1-30pp
- Hill G.; Waage J. and Phiri G. (1997) "The Water Hyacinth Problem in Tropical Africa" In *Proceedings of the International Water Hyacinth Consortium* Delfosse E.S. and Spencer N.R (eds.), World Bank, Washington D.C 18-19 March, 1997.
- Hirji R. and Carey D. (1998): "Managing International Waters in Africa: Process and Progress" in Salman M.A S and Boisson de Chazournes L (eds.) 1998: *International Watercourses; Enhancing Cooperation and Managing Conflict: seminar proceedings*, World Bank technical paper No 414.
- Horenstein N (1989) *Women and Food Security in Kenya*. PPR working paper, WPS 232, World Bank, Washington D.C.
- Hossain M. (1988) *Credit for Alleviation of Rural Poverty: The Grameen Bank in Bangladesh*, Research Report 65, IFPRI/BIDS
- Houthakker, H.S. (1987) Ernst Engel. In: *The New Palgrave: A Dictionary of Economics* edited by J. Eatwell, M. Milgate and P. Newman, Vol 2 p142-144, The Macmillan Company, New York.
- Houthakker, H.S. (1987) household budgets In: *The New Palgrave: A Dictionary of Economics* edited by J. Eatwell, M. Milgate and P. Newman, Vol 2 p142-144, The Macmillan Company, New York.
- Ikiara, M.M. (1999) Sustainability, Livelihoods, Production and Effort Supply in a Declining Fishery: The Case of Kenya's Lake Victoria Fisheries. Unpublished PhD dissertation, Universiteit van Amsterdam, Faculteit der Economische wetenschappen Econometrie, The Netherlands.
- Iman R.L and Conover, W.J. (1978) Approximation of the Critical Region for Spearman's Rho With and Without Ties Present, *Communications in Statistics, Series B*, 7: 269-82
- Ivens, G.W (1982) *East African Weeds and their Control*, Oxford University Press, Nairobi.
- Jaetzold R. and Schmidt H. (1982) *Farm Management Handbook of Kenya-Natural Conditions and Farm Management Information*, Vol II/A-West Kenya, Ministry of Agriculture/GTZ, Nairobi.
- Johnson, M.; McKay A.D.; and Round J.I (199?) *Income and Expenditure in a System of Household Accounts: Concepts and Estimation*. SDA

- working paper no. 10, surveys and statistics, World Bank, Washington D.C.
- Kakwani N and Subbarao, K (1993) 'Rural Poverty in India 1973-87' In: Including the Poor: proceedings of a conference organised by the World Bank and IFPRI. Michael Lipton and Jacques van der Gaag (eds.) pp 413-462
- Kaufman L (1992) Catastrophic Changes in Species-rich freshwater ecosystems: the Lessons from Lake Victoria. In: *BioScience* 42 (11): 846-858
- Kennedy, E.T. (1989) *The Effects of Sugarcane Production in Food Security, Health, and Nutrition in Kenya: A Longitudinal Analysis*. IFPRI Research Report 78, IFPRI, Washington D.C.
- Kennedy, E.T. and Cogill, B. (1987) *Income and Nutritional Effects of the Commercialization of Agriculture in Southwestern Kenya*, IFPRI Research Report No. 63. IFPRI, Washington D.C.
- Kimuyu, P. (2000) Budgeting for Poverty Reduction in Kenya: IPAR's contribution to Kenya's Poverty Reduction strategy Paper (PRSP) 2000-2003. In *Policy quarterly*, IPAR, issue No 4, May 2000.
- Kiss, A.C. (1983) *Selected Multilateral Treaties in the Field of the Environment*, UNEP reference series 3, Prudential publishers, Nairobi.
- Koutsoyannis (1979) *Modern Microeconomics*, Second edition, Macmillan, London 581pp
- Kusewa T.M., Okeyo-Owuor J.B., Ochiel G.R.S and Gitonga W (2000) Fungi Associated with Diseased Water Hyacinth (*Eichhornia crassipes*) in Kenya. Paper prepared for the Second Global Working Group Meeting for the Biological Control and Integrated Control of Water Hyacinth, October 9-12, Beijing, China.
- Lewis, L.A and Berry, L (1988) *African Environments and Resources*, First edition, Unwin Hyman Ltd, Teachers annotated ed. Columbus, Ohio pp56-73
- Lindsey, K. and Hirt, Hans-Martin (2000) *Use Water Hyacinth! A practical handbook of uses for the water hyacinth from across the world*, Marianum Press, Kisubi, Uganda.
- Lipsey R.G and Chrystal K.A (1995) *An Introduction to Positive Economics*, Eighth edition, ELBS edition, Oxford University Press, Oxford
- Lovie P. and Lovie A.D. eds. (1991) *New Developments in Statistics for Psychology and the Social Sciences*, Vol 2 BPS and Routledge, London.
- Lund, S.M (1996) *Informal Credit and Risk-Sharing Networks: Empirical Evidence from the Philippines*, Manuscript, Stanford University
- Madati P.J; Berege E.; Mosha D., Moshi A., Mongi H., Shikony E. (1982) The Current Situation on Water Quality and Pollution Problems in Tanzania. In: Okidi, Charles O. and Olindo, P.M. (eds.) *Quality of water and its impact on the living resources of the Lake Victoria basin*. A workshop report, Kisumu pp64-87.
- Maddala G.S. and Miller E (1989) *Microeconomics: Theory and Applications*, McGraw-Hill book company, New York.
- Mailu A.M (ed) (1998) *Water Hyacinth Control Bulletin*, No 1, Kenya Agricultural Research Institute, Nairobi June, 1998

- Mailu A.M. (1999) Assessment of Social, Economic and Environmental Impacts of Water Hyacinth in Lake Victoria, paper presented at a workshop in Entebbe Uganda under the auspices of the Economic Commission for Africa-East Africa Subregional Development Centre, Kigali, Rwanda.
- Mailu S.K., Mailu A.M. Gitonga W., Ochiel G.R.S. and Njoka, S.W. (2002) Biological or Physical Waterhyacinth Control? An Analysis of Implied Quality, Paper presented at the IPM Conference for Sub-Saharan Africa, Kampala, 8-12, 2002.
- Mailu S.K.; Kidula N.L and Njue E.K (1998) Formal and Informal Credit in Southwestern Kenya: Implications for Agricultural Research and Policy In: KARI/DfID NARPII End of Project conference proceedings Sutherland (ed), March 23 1999
- Mailu, A.M., Ochiel, G.R.S. and Gitonga W. (1999) Water hyacinth: distribution, impact and control measures KARI Technical Notes Series No. 3 February 1999, 8 pp. + illustrations
- Makinde K.O., Manyong V.M. and Olayemi J.K. (2001) Socioeconomic Determinants of Farm Household Expenditure in Bauchi, Nigeria **In:** Tenywa, J.S., Nampala, P. Tusiime, G and Osiru, M. (eds) African Crop Science Conference Proceedings, October 2001, Vol 5, part 2 of 2, pp 723-728.
- Maxwell D., Levin C., Armar-Klemesu M., Ruel M., Morris S., and Ahiadeke C. (2000) Urban Livelihoods and Food and Nutrition Security in Greater Accra IFPRI (in collaboration with Noguchi Memorial Institute for Medical Research and World Health Organisation. Research report No. 112, IFPRI Washington D.C.
- MCBI (1998): Scientists call on Secretary Babbitt to keep noxious seaweed out of US waters. Online at: <http://mcbi.org/caulerpa/caulerpa.html>
- Miller R.R.; J.D. Williams and J.E. Williams (1989) Extinctions of North American Fishes during the Past Century. *Fisheries* 14 (6): 22-38
- Mitchell, D.S.; Pieterse, A.H.; and Murphy K.J. (1990) Aquatic Weed Problems and Management in Africa. In: *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation* Arnold H. Pieterse and Kevin J. Murphy (eds.) 1990; OUP, New York.
- Moorhouse, T.M.; Agaba, P. and McNabb, T.J. (2001) Recent Efforts in Biological Control of Water Hyacinth in the Kagera River Headwaters of Rwanda **In:** M.H. Julien; M.P. Hill; T.D. Center and D. Jianqing (eds) *Biological and Integrated Control of Water Hyacinth (Eichhornia crassipes)* ACIAR Proceedings, No. 102, p39-42.
- Msambichaka L.A. (1995): Stakeholder Consultation and Community Participation in Tanzania, Draft report, UNDP-Lake Victoria Environmental Management Programme, Dar es Salaam, September 1995
- Muli, J.R. (1996) Environmental Problems of Lake Victoria (East Africa): What Can the International Community Do? In: *Lakes and Reservoirs Research and management* 1996 2:47-53.
- Munasinghe, M. and Lutz, E. (1993) 'Environmental Economics and Valuation in Development Decisionmaking'. In: Munasinghe (ed) *Environmental*

- Economics and Natural resource Management in Developing countries*, World Bank, Washington D.C.
- Narayan D. and Nyamwaya D. (1995) A Participatory Poverty Assessment Study—Kenya. Report prepared for the World Bank sponsored by ODA/UNICEF. Nairobi.
- Narayan D. and Pritchett L. (1996) *Cents and Sociability: Household Income and Social Capital in Rural Tanzania*, Fourth Annual World Bank Conference on Environmentally Sustainable Development, September 25-27, 1996.
- Narayan D. and Pritchett L. (2000) Social Capital: Evidence and Implications: In *Social Capital: A Multifaceted Perspective* Partha Dasgupta and Ismail Serageldin (eds.) 2000 The World Bank, Washington D.C. pp269-295
- NASA (1996) Success at Stennis: A New Image for the Water Hyacinth. Available online at: <http://www.nasa.gov/>
- National Task Force (1988) Agroforestry potentials for the land use systems in the bimodal highlands of Eastern Africa, Kenya. *Arena Report* No. 3, Agroforestry Research Networks for Africa, ICRAF, Nairobi.
- News Service, (1999) Kenyan, Bangladeshi Artisans Share Ideas on Creative Uses for Tropical Water Weed. <http://www.>
- Nganda, B.M. (1996) 'The role of Markets in the worsening Epidemiological Environment'. In: *Environment and Development Economics* Vol 1, part 3, July 1996, pp 371-375.
- Njoka T., Gibbons, W.M., Dewees P., Kamweti, D., (1988) The Status of Natural resources in Kenya: Report to USAid/Kenya Natural Resources Management Support Project. Working paper No 1, Louis Berger Int, inc. Nbi, Kenya
- Nkuba, R.M. (1997) A Preliminary Assessment of the Economic Impact of Water Hyacinth in Uganda In: Adipala, E; Tusiime, G and Okori, P (eds) Proceedings of the 16th Biennial Weed Science Society Conference for Eastern Africa, Kampala, 15-18 September, 1997, pp 279-286.
- Obeid, M. (1975) The Water Hyacinth (*Eichhornia crassipes*) (Mart.) (Solms.) In: M. Obeid (ed) *Aquatic weeds in the Sudan*, National Council for Research, Khartoum, Sudan
- Ochiel G.S., Njoka, S.W., Mailu, A.M and Gitonga W. (2001) Establishment, Spread and Impact of *Neochetina* sp Weevils (Coleoptera: Curculionidae) on Water Hyacinth *Eichhornia crassipes* (Liliales: Pontederiaceae) in Lake Victoria, Kenya. In: M.H. Julien; M.P. Hill; T.D. Center and D. Jianqing (eds) *Biological and Integrated Control of Water Hyacinth (Eichhornia crassipes)* ACIAR Proceedings, No. 102, p89-95.
- Ochieng, W.R (1979) *Kenya's People: People Around The Lake*, Evans Brothers, London, 1979
- Ocholla-Ayayo, A.B.C. (1976) *Traditional Ideology and Ethics among the Southern Luo*, The Scandinavian Institute of African Studies, Uppsala.
- Ochumba P.B.O (1994) Conservation Plan for Lake Victoria In: Muchura J.E. (ed) SWARA: Magazine of the East African Wildlife Society, Nairobi 17: (2) pp16-19

- Ogutu G.E.M. (1988) Artisanal Fisheries of Lake Victoria, Kenya: Options for Management, Marketing and Production. Workshop proceedings, 24-26th Nov 1988, IDRC Kisumu, Shrikon publishers for the artisanal Fisheries (Kenya), pp1-22
- Ogwang J.A. and Molo R. (1997) Biological Control of Water Hyacinth in Uganda In: Adipala, E; Tusiime, G and Okori, P (eds) Proceedings of the 16th Biennial Weed Science Society Conference for Eastern Africa, Kampala, 15-18 September, 1997, pp 287-293.
- Okallo, D. D. (1999) "Socioeconomic Impacts of the Water Hyacinth in Lake Victoria on Fishing and Trading Communities: A Comparative Rural and Urban Case Study in Kisumu", Unpublished MPhil Thesis, Moi University.
- Okeyo-Owuor J.B (1999): *A Review of Biodiversity and Socio-economics Research in Relation to Fisheries in Lake Victoria*, Report No 5, IUCN-Eastern Africa Programme.
- Okidi C.O (1988) The State and the Management of International Drainage Basins in Africa, *Natural Resources Journal*, Vol 28 (fall, 1988) Univ. of New Mexico, pp 645-669
- Okidi C.O. (1990) History of the Nile and Lake Victoria Basins through Treaties: paper presented at the conference on the Nile convened at the Royal Geographical Society and the University of London (SOAS), 2-3 may, 1990.
- Okidi, C.O. (1994) *Environmental Stress and Conflict in Africa: Case Studies of Drainage Basins*. Ecopolicy Series, No 6: ACTS Press & MUSES.
- Okidi, C.O. and Olindo, P.M. (eds.) (1982) Quality of water and its impact on the living resources of the Lake Victoria basin. A workshop report, Kisumu 1-56pp.
- Okunde, A.A. (1985) Engel Curves for Developing Nations: The Case of Africa. In: *East African Economic Review* Vol 1, No 1, Dec 1985 pp13-22
- Ongweny, G.S. (1979) Water Resource of Lake Victoria Drainage Basin in Kenya. In: *Natural Resources and Development of Lake Victoria Basin of Kenya*, C.O Okidi (ed) pp 68-84, University of Nairobi, IDS/OP 34.
- Opondo F..A. (1988) Rural Household Budget Survey, 1981/82 Highlights In: *Kenya Symposium on Statistical Surveys: Integrating Population Data into National Development*. CBS/MPND, Government Printer, Nairobi. (CBS/NS/28) pp135-147
- Ostrom, E. (1990) *Governing the Commons: the Evolution of Institutions for Collective Action*. Cambridge (UK): Cambridge University Press
- Ostrom, E. (1994) *Neither Market Nor State: Governance of Common-Pool Resources in the Twenty-first Century*. IFPRI Lecture series 2, IFPRI, Washington D.C.
- Otieno, D.A., and Wangila, B.C.C., (1993) Protection and Environmental Management of Biological Diversity in the Lake Victoria Basin. A concept paper presented at a workshop held at the University of Amsterdam, 1-2 April 1993 to consider the research project: Protection of Environmental and Biological Diversity in the Lake Victoria Basin.
- Panayoutou, T. (1982) Management Concepts for small scale fisheries economic and social aspects FAO Fish Technical paper (228):53p

- Pearce D.W. (1992) *Macmillan Dictionary of Modern Economics* 4th edition, Macmillan press, London.
- Pearce D.W. and Turner (1990) *Economics of Natural Resources and the environment*, Harvester Wheatsheaf, U.K.
- Perman, R., Ma, Y., McGilvary, J. and Common, M. (1999) *Natural Resource and Environmental Economics*, 2nd edition Longman Publishers.
- Pieterse A.H. (1990) Biological Control of Aquatic Weeds **In:** *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation* A.H. Pieterse and K.J. Murphy (eds.) 1990; Oxford Science Publishers, New York. pp174-221
- Ravallion, M. (1992) *Poverty Comparisons: A Guide to Concepts and Methods*. LSMS Working Paper, No. 88, World Bank, Washington D.C.
- Republic of Kenya (1991) *National Atlas of Kenya*, Fourth edition, 1991. Survey of Kenya, Nairobi.
- Republic of Kenya (1994) *Kenya Population Census 1989: Analytical Report Vol IX*, CBS/OVP-MPND, Government Printer, Nairobi.
- Republic of Kenya (1996) *Welfare Monitoring Survey II 1994: Basic Report*. CBS/OVP/MPPND, Government Printer?, Nairobi.
- Republic of Kenya (1997) *The Second Participatory Poverty Assessment Study—Kenya*. Volume 1. Report prepared by AMREF and the HRSSD of the office of the Vice President, MPND. Government Printer, Nairobi
- Republic of Kenya (1998) *First Report on Poverty in Kenya Volume II: Poverty and Social Indicators*. A report presented by the CBS and HRSSD, MPND. Government Printer, Nairobi.
- Republic of Kenya (1999) *A Popular Version of the First Poverty Report in Kenya*. Report prepared by CBS/HRSSD, OVP/MPPND, Government printer Nairobi.
- Republic of Kenya (1999) *The Environmental Management and Coordination Act, 1999 No. 8 of 1999*, Government Printer, Nairobi
- Republic of Kenya (2000) *Second Report on Poverty in Kenya: Vol 1: Incidence and Depth of Poverty*. Ministry of Finance and Planning, Government printer? Nairobi.
- Republic of Kenya, (1997) *Economic Survey, 1997* Office of the Vice President and Ministry of Planning and National Development, CBS, May, 1997 Government Printer, Nairobi.
- Republic of Kenya, (1998) *Economic Survey, 1997* Central Bureau of Statistics, Ministry of Planning and National Development, May, 1998, Government Printer, Nairobi.
- Roach John (1999) "Satellite Uncovers Lake Victoria Pollution": http://www.enn.com/news/enn_stories/1999/11/110899/victoria_709_0.asp
- Scheaffer, Richard L; Mendenhall W.; and Ott, L. (1990) *Elementary Survey Sampling*, fourth edition. Duxbury press, USA.
- Schmidt-Hebbel, K and Servén, L. (1997) *Saving across the World: Puzzles and Policies*, World Bank Discussion Paper number 354, The World Bank, Washington D.C.
- Scott C. and Amenuvegbe B. (1990) *Effect of Recall Duration on Reporting of Household Expenditures: An Experimental Study in Ghana*. SDA Working Paper Series, No 6 Noël Michael (ed), The World Bank, Washington D.C.

- Seralgedin, I. and Grootaert, C. (2000) 'Defining Social Capital: an Integrating View'. In: *Social Capital: A Multifaceted Perspective* Partha Dasgupta and Ismail Seralgedin (eds.) The World Bank, Washington D.C.
- Shabana, Y.M., El Wakil M.A., and Charudattan, R. (2000) The Story of Biological Control of Water Hyacinth by a Mycoherbicide in Egypt Paper presented during the Second Global Working Group Meeting for the Biological Control and Integrated Control of Water Hyacinth, October 9-12, Beijing, China.
- Singh, I., Squire L. and Strauss, J. (1986) *Agricultural Household Models: Extensions, Applications and Policy*. Published for the World Bank by The John Hopkins University Press, Baltimore, Maryland.
- Smith, L.C. and Haddad, L. (2000) Explaining Child Malnutrition in developing Countries: A Cross Country Analysis. IFPRI Research report 111 (abst) Available Online at : <http://www.ifpri.org/pubs/abstract/abstr111.htm>
- Stiglitz, J.E. (2000) Formal and Informal Institutions :In *Social Capital: A Multifaceted Perspective* Partha Dasgupta and Ismail Seralgedin (eds.) 2000 The World Bank, Washington D.C.
- Täckholm, V. and Drar M. (1950) Flora of Egypt; Vol II Cyperaceae-Juncaceae Bull. Fac. of Science No 28 Fouad I univ press, Cairo.
- The East African* (2001) 'Fish in Lake Victoria Down by 0.6m' by W. Wakabi: Issue no 364, October 22-28, 2001, published by the Nation Group.
- Thompson, K. (1991) The Ecology of the Water Hyacinth and its Distribution in Uganda. Pp 24-36. In: Thompson, K. (ed) *The Water Hyacinth in Uganda: Ecology, Distribution, Problems and Strategies for Control. Proceedings of a National Workshop, 22-12 Oct 1991, Kampala, Uganda, UN/FAO, Kampala.*
- Tjitrosoedirdjo S.S. and Wifoatmodjo, J. (1984) Water Hyacinth Management in Java. Indonesia. In: *Proceedings of the International Conference on Water Hyacinth*. Thyagarajan, G. (ed), pp 176-192, UNEP, Nairobi.
- Twongo, T. and Balirwa, J. (1995) The water hyacinth problem and the biological control option in the highland lake region of the upper Nile Basin: Uganda's experience. Paper presented at the Nile 2002 conference.: Comprehensive Water Resources Development of the Nile Basin, Feb 13-17 1995, Arusha
- UNEP (1999) *Industry and Environment: Changing Consumption Patterns*, quarterly review, Volume 22 No 4 October-December 1999. UNEP, Division of Technology, Industry and Economics, Tour Mirabeau, 39-43 quai André-Citroën, 75739 Paris Cedex 15, France
- UNEP, (1993) *United Nations Environmental Programme: Environment Data Report, 1993-94*, Blackwell publishers, Oxford
- UNICEF (1998): *The State of the Worlds Children—1998*, Oxford University press, New York.
- UNOHCHR (2002) Draft Guidelines: A Human Rights Approach to Poverty Reduction Strategies, Office of the High Commissioner for Human Rights, Geneva.
- USGS, (1999) 'West Nile virus may be new deadly strain' U.S. Geological Survey, News Release, December 14, 1999. Online at:

http://www.usgs.gov/public/press/public_affairs/press_release/pr1128.html

- Varian R. H. (1990) *Intermediate Microeconomics: A Modern Approach*, second edition, W.W. Norton & Co, New York.
- Von Braun, J., de Haen H. and Juergen B. (1991) *Commercialization of Agriculture under Population Pressure: Effects on Production, Consumption and Nutrition in Rwanda*. IFPRI Research Report 85, IFPRI, Washington D.C.
- Waage J.K. and Greathead D.J. (1988) Biological Control: Challenges and Opportunities. *Philosophical Transactions of the Royal Society of London, Series B*, 318, pp111-128
- Wade P.M (1990) Physical Control of Aquatic Weeds **In: Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation** A.H. Pieterse and K.J. Murphy (eds.) 1990; Oxford Science Publishers, New York. pp93-135
- Wallis Nicholas J.A (1997) *Intensified Systems of Farming in the Tropics and Subtropics*: World Bank Discussion Paper No 364, The World Bank, Washington D.C.
- Wanmali Sudhir (1992) *Rural Infrastructure, the Settlement System and the Development of the Regional Economy in Southern India*, IFPRI research report No 91, IFPRI, Washington D.C.
- Wawire N.W. and Ochiel, G.R.S (2001) A review of the impact of water hyacinth on Lake Victoria: the case of Winam Gulf, Kenya. Paper presented at the 1st LVEMP National Scientific Conference on Lake Victoria Tom Mboya Labour College, Kisumu, Kenya 24-28 September, 2001
- Wilson, D.C., M. Medard, C.K. Hariss (1999) The Implications for Participatory Fisheries Management of Intensified Commercialisation on Lake Victoria. in: *Rural Sociology* 64(4), 1999 pp554-572.
- Woomer, P.L. (1997) Managing Water Hyacinth Invasion Through Integrated Control and Utilisation: Perspectives for Lake Victoria. In: *African Crop Science Journal*, 5: 309-325.
- World Bank (1992) *World Development Report 1992: Development and the Environment*, Oxford University Press
- World Bank (1997) *African Development Indicators 1997*: The World Bank, Washington D.C.
- World Bank (2001) *World Development Report 2000-2001: Attacking Poverty*, Oxford University Press, 2001.
- WRI (1992) *World Resources 1992-1993: Toward Sustainable Development :A Guide to the Global Environment* WRI/UNEP/UNDP. Oxford University Press, New York
- WRI (2000) *World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life*, WRI, Washington D.C.
- Zeller, M. et Sharma, M. (1998) *Finance Rurale et Reduction de la Pauvrete*, Rapport de Politique Alimentaire, Institut International de Recherche sur les Politiques Alimentaires, Washington D.C.

Appendix : Infestation level card



Heavy Infestation [LEVEL 1]



Moderate Infestation [LEVEL 2]



No Hyacinth—for contrast and comparison [LEVEL 3]